REPORT RESUMES

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EXPERIMENTATION WITH COMPUTER-ASSISTED INSTRUCTION IN TECHNICAL EDUCATION. SEMI-ANNUAL PROGRESS REPORT.
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THE THIRD 6-MONTH PERIOD OF OPERATION OF A COMPUTER-ASSISTED INSTRUCTION (CAI) EFFORT IN TECHNICAL EDUCATION WAS COVERED IN THIS REPORT. THE OBJECTIVES OF THE TOTAL PROGRAM (A 4-YEAR EFFORT) WERE (1) TO COMPARE CAI WITH OTHER EDUCATIONAL STRATEGIES, (2) TO PREPARE INSTRUCTIONAL MATERIALS, (3) TO TRAIN PERSONNEL, AND (4) TO DISSEMINATE RESULTS OF RESEARCH. FIVE BARRIERS TO THE DEVELOPMENT OF CAI WERE DISCUSSED--(1) DELAY OF PROGRAM DEVELOPMENT WAITING FOR IMPROVED HARDWARE AND VICE VERSA, (2) LACK OF EXPERIENCE AND METHODOLOGY FOR CONSTRUCTION OF ACHIEVEMENT MEASURES, (3) EXCESSIVE TIME REQUIRED TO WRITE A CAI PROGRAM, (4) LACK OF KNOWLEDGE OF THE APPROPRIATE BALANCE BETWEEN CAI AND TEACHER INSTRUCTION, AND (5) RESTRICTION OF EXCHANGE OF CAI PROGRAMS DUE TO LACK OF COMPATIBILITY OF COMPUTERS. IT WAS CONCLUDED THAT IT WAS INAPPROPRIATE AT THE TIME OF REPORTING TO MAINTAIN THAT CAI DOES OR DOES NOT PROVIDE MORE EFFICIENT METHODS OF TEACHING. (AL)

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COMPUTER ASSISTED INSTRUCTION LABORATORY

COLLEGE OF EDUCATION · CHAMBERS BUILDING

THE PENNSYLVANIA STATE UNIVERSITY · UNIVERSITY PARK, PA.

EXPERIMENTATION WITH COMPUTER-ASSISTED INSTRUCTION IN TECHNICAL EDUCATION

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SEMI-ANNUAL PROGRESS REPORT

DECEMBER 31, 1966

THE PENNSYLVANIA STATE UNIVERSITY
COMPUTER ASSISTED INSTRUCTION LABORATORY
UNIVERSITY PARK, PENNSYLVANIA

Semi-Annual Progress Report

EXPERIMENTATION WITH COMPUTER-ASSISTED INSTRUCTION IN TECHNICAL EDUCATION

Project No. 5-85-074

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CHAPTER I

INTRODUCTION

This report spans the third six months period (July 1, 1966 to December 31, 1966) of operation of a computer-assisted instruction (CAI) effort in technical education and is designed to show Penn State University's stewardship of its own resources and the federal funds awarded to it under the provisions of Section 4(c) of the Vocational Education Act of 1963.

Briefly, the objectives of the original proposal were as follows:

1. To evaluate the articulation of computer-assisted instruction with other educational strategies and, by means of careful experimentation, determine optimum ways of presenting core courses in technical education curricula.
2. To prepare curriculum materials for computer presentation with emphasis on the instruction of post-high school students in technical mathematics, engineering science, and communication skills.
3. To train an interdiciplinary group of individuals to prepare course materials and to do research on computer application in technical education.
4. To disseminate the information and evidence concerning the innovation of CAI and its application to occupational education.

Progress has been made toward all of these objectives and the evidence is detailed in the following report. The first chapter deals with the physical facilities provided by the University, the equipment configuration in operation during the past six months, and a digest of the Coursewriter language now being used by investigators in the Laboratory. Chapters II through IV describe the course development activities in technical education subjects Brief reports of research findings are presented in Chapter V.

The project has been programed for an additional 30 months in which further attempts will be made to establish reliable knowledge concerning the application of the computer-assisted instruction technology to the field of occupational education.

Physical Facilities and Equipment

For the past year, the project has been housed in recently remodeled quarters located in 201 Chambers Building, at The Pennsylvania State University, University Park, Pennsylvania. The new quarters provide ample office space for approximately ten professional staff members, ten graduate research assistants, and ten technicians. In addition to the office space for staff members, the Laboratory contains four air-conditioned, sound-proofed terminal rooms, two 8' 4" x 6' and two 6' 2" x 6', each containing one CAI student terminal, audio-visual components, and a printing desk calculator.

The Laboratory is operating by means of dial access telephone to an IBM 1410 computer system which is housed in the Computation Center on the Penn State campus. In addition to the four terminals which are located in the CAI Laboratory on the campus, two terminals are now operating at the Williamsport Area Community

College, Williamsport, Pennsylvania, and two are located in Ivyside Building at Penn State's Commonwealth Campus in Altoona, Pennsylvania. CAI course materials are teleprocessed to students at these remote locations from the 1410 computer on the main campus. Students at the Williamsport Area Community College and at the Altoona Campus have been receiving computer-assisted instruction and have been participating in experiments since August, 1966.

An IBM Magnetic Tape "Selectric" Typewriter and a 1056 Card Reader have been acquired during the period to accelerate the preparation and computer input of CAI course materials.

Summary of Coursewriter Author Language

The courses listed in Table 1.1 have been written in the CAI author language known as Coursewriter. A complete description of Coursewriter is beyond the scope of this report; however, a summary of the functions of each of the operation codes in the language is provided below. This list covers most of the basic operations in the language. However, an author wishing to prepare CAI programs should study the more detailed Coursewriter manual (Coursewriter, 1965). In addition, Gilman and Harvilchuck (1967) have developed a set of training materials for providing new authors with instruction in the use of the Coursewriter language. These materials will be reproduced as a separate technical report of the Penn State CAI Laboratory in the near future.

Summary of Coursewriter Operation Codes

Primary

rd - Computer types text and waits for the student to signal completion. Commonly used to display a reading assignment to a student.

rdn- Same as rd, but does not update restart address.

qu - Computer types text and waits for student to type a response. Commonly used to display questions or problems to a student.

qun- Same as qu, but does not update restart address.

Major

ca - Correct answer to be stored in memory for comparison with student's answer.

cb - Similar to ca -- used to identify a set of alternate correct answers-- the subsequent action is to be the same regardless of which answer in the set is matched by the student's response.

wa - Wrong answer to be stored for comparison with student's answer.

wb - Similar to wa - used to identify a set of alternate wrong answers - the subsequent action is to be the same regardless of which answer in the set is matched by the student's response.

aa - Anticipated answer - similar to ca and wa, but not followed by implicit branch.

ab - Similar to aa - used to identify a set of alternate anticipated answers - the subsequent action is to be the same regardless of which answer is matched by the student's response.

un - Text to be typed if the student's answer is not one of the specified correct or wrong answers.

nx - Instructs the computer to execute the instruction(s) immediately following the nx. The purpose of the nx is to change a minor operation code (e.g., ty or fn) to a major operation code.

xl - Time limit -- computer ignores anything typed by the student after the specified time has lapsed.

Minor

ty - Computer types text and continues without waiting for any response from the student.

br - Branch -- alters the sequence of execution
Unconditional: branch is always taken
Conditional: branch is taken only if a particular condition is satisfied.

ad - Adds (algebraically) a number or the contents of a counter to a counter. Commonly used for accumulating a student's errors or response times.

ld - Load -- clears a counter and adds a number (or the contents of a counter) into a counter. Load may also be used to set a switch to 0 or 1.

dv - Divide contents of a counter by a constant or by the number in a counter.

mp - Multiply contents of a counter by a constant or by the number in a counter.

fp1- Display a slide.

fp0- Seek and position a slide, but does not display it.

tp1- Play a tape recorded message.

tp0- Seek and position tape recorded message but does not play it.

tpr- Record a tape recorded message.

fn - Computer executes the specified function. Functions are special series of instructions (written in a machine language subprogram) so that the computer can do processing which cannot be done by using only the Coursewriter operation codes.

fn - slide//n - The display slide function is used to present a slide; n represents the number of the slide to be displayed.

fn - slide//nx - The seek and position slide function will seek and position slide n, but will not show the slide until a display slide function occurs in the program.

fn - tape//n - The play tape function will play tape recording number n.

fn - tape//nx - The seek and position tape function causes tape recording number n to be positioned. The recording will not play until a tape play function occurs in the program.

fn - dc// - The display c-counter function is used to display the contents of a c-counter to the student.

fn - dx// - The display x-counter function is used to display the contents of an x counter to a student.

fn - wait// - The wait function allows the author to delay the program before execution.

fn - kw// - The key word function allows the author to specify one or more key words which must be matched in the student's answer.

fn - kwo// - The key words ordered function is similar to the key word function. However, the key word ordered function also requires that the matched key words in the student's response are entered in a specified order.

fn - kwi// - The key words initial function searches for the words that have been entered in the ca or wa. If the function finds a word in the student's response not in the ca or wa, the function is terminated.

fn - kw//io - The key words ordered and initial function searches for key words in the student's response. This function insists that the student's response be in a certain order and also checks to insure that there are no unmatched key words in the student's response.

fn - lim - The limits function allows the author to specify mathematical limits within which the student's numerical response will be acceptable.

fn - pa0// - The partial answer zero function allows an author to disregard extraneous discrepancies between a student's response and the text of a ca, wa, or aa. This function is used to process answers which are misspelled or partially correct.

fn - irand// - The pseudo random integer function allows authors to specify that a pseudo random integer be placed in a c-counter.

fn - ic// - The initial characters function allows authors to specify that only a certain designated number of initial characters in the student's response are to be compared with a subsequent ca or wa. The function also allows the author to specify that characters in certain positions of the student's response are irrelevant and are to be considered matched.

fn - ed// - The edit function allows an author to edit the student's response by replacing or deleting characters.

fn - sb// and rb// - The save and branch function (sb) allows the author to insert in one place within a course a certain sequence of material (subroutine) which can be branched to repeatedly thus limiting the necessity for programming the same material at repeated places within the course. The return branch (rb) function returns the student to a point in the course as directed by an address indicated in the text of the sb function.

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Development of CAI Course Materials in Technical Education

Summary of Course Materials Developed, Tested, and Revised

One objective of the Penn State CAI Laboratory is to produce useful educational products in the form of CAI programs for post-high school technical education programs. The majority of CAI programs developed in the Laboratory are experimental in the sense that they have been designed to explore teaching strategies, and to develop the unique instructional capabilities of a high-speed electronic computer. Although the CAI courses are being developed in small segments for experimental purposes, many of these segments appear to have practical utility as instructional materials. Preliminary evaluations of several courses have been completed and the data are encouraging with regard to the degree of student learning resulting from the courses.

Course segments are being developed in three major areas: Engineering Science, Technical Mathematics, and Communication Skills. Table 1.1 represents an accumulative summary of all CAI course segments developed on the project as of December 31, 1966. The table indicates the extent to which each course segment utilizes audio-visual communication, static displays, the number of students who have taken the course to date, the total number of system hours of student instruction, the length of each course segment estimated by the average time taken per student to complete instruction, and a column indicating whether the course segment has been revised following the examination of student performance on the course.

Table 1.1

Summary of Course Materials
Developed, Tested, and Revised
as of December 31, 1966

Course Segment	No. of Slides	No. of Tape Messages	No. of Static Displays	No. of Students	Total System Time on Course Segment HRS/MINS		Est. Avg. Student Time HRS/MINS		Revised following evaluation?
Communication Skills:									
Spelling Introduction	2	3	--	36	9	0	0	15	yes
Vocabulary	9	12	--	36	15	0	0	25	yes
Diagnostic Test	--	37	--	25	25	0	1	0	yes
Plurals	15	--	--	8	6	0	0	45	yes
Suffixes	--	10	--	5	3	45	0	45	yes
Words with "e" or "y"	1	1	--	7	2	20	0	20	yes
Syllables	--	15	--	12	6	0	0	30	yes
Words with "i" or "e"	--	10	--	2	0	40	0	20	yes
Compounds	--	--	--	6	3	0	0	30	yes
Discrimination	4	29	--	1	0	35	0	35	yes
Homonyms	--	10	--	17	11	14	0	37	yes
Demons	--	29	--	19	11	5	0	35	yes
Proofreading	--	--	1	25	12	30	0	30	--
Posttest	--	36	--	25	25	0	1	0	--
State Capitals - Paired-Associate Learning									
Keyword Function	--	--	--	10	25	40	2	34	yes
Partial Answer Processing	--	--	--	8	22	30	2	48	yes

Course Segment	No. of Slides	No. of Tape Messages	No. of Static Displays	No. of Students	Total System Time on Course Segment HRS/MINS		Est. Avg. Student Time HRS/MINS		Revised following evaluation?
Technical Mathematics:									
Converting Number Systems	--	--	4	87	187	30	2	10	yes
Metric System	4	--	--	4	4	0	1	0	yes
Significant Figures	17	13	--	5	9	0	1	45	yes
Intro. to Math. Prob. Solv.	--	--	--	3	3	0	1	0	yes
Kinematics & Calculus	9	11	--	6	4	0	0	40	yes
Vector Analysis	17	13	--	--	0	0	2	0	--
Trigonometry	31	20	20	7	9*	0	3	30	yes
Printing Calculator	3	3	4	--	0	0	0	0	--
Significant Figures 1	--	--	7	14	22	30	1	30	yes
Sigfig100	--	--	7	29	40	50	1	25	yes
Sigfig101	--	--	7	36	48	0	1	20	yes
Sigfig200	--	--	7	11	15	0	1	15	yes
Exponential Rules and Logarithms	13	--	13	--	--	--	2	0	--
Engineering Science									
Intro. to Physics	10	8	--	2	1	45	0	52	yes
Working with Units	9	2	--	55	88	6	1	29	yes
(flbr	9	2	--	2	2	30	1	15	yes
(flcr	9	2	--	26	29	45	0	68	yes
(flsk	9	2	--	20	18	0	0	52	yes
(medl 3 versions)	9	2	16	115	115	0	1	0	yes

---

*Represents student instruction time to cover one segment only.

Course Segment	No. of Slides	No. of Tape Messages	No. of Static Displays	No. of Students	Total System Time on Course Segment		Est. Avg. Student Time		Revised following evaluation?
					HRS/MINS		HRS/MINS		
Scientific Notation	25	--	--	4	4	0	1	0	yes
Atom	20	19	--	14	12	30	1	0	yes
Basic Magnetism	12	7	--	2	2	30	1	15	yes
Optics, Part I	28	0	--	--	--	--	1	30	--
Optics, Part II	31	0	12	--	--	--	1	30	--
Electrostatics	22	13	--	--	--	--	2	15	--
Micrometer & Vernier Caliper	14	--	14	--	--	--	2	0	--
Heat, Part I	29	--	--	--	--	--	2	0	--
Heat, Part II	15	--	--	--	--	--	1	30	--
Differential Knowledge Results:									
Area of Mechanics	50	--	--	--	--	--	1	0	--
Science Misconceptions	30	--	--	--	--	--	2	0	--

Five Major Barriers to the Development of Computer Assisted Instruction

Harold E. Mitzel

There are at least five plausible, more or less accurate definitions of computer-assisted instruction: (1) computer terminal as an adjunct calculating device and laboratory instrument used in a typical classroom, usually where mathematics or physics is taught; (2) computer used as a record keeper and retriever of student biographical and performance data; (3) computer simulation of real-life problem-solving, i.e., medical diagnosis, equipment trouble shooting, etc.; (4) computer as a recitation-receiving and evaluation device or "homework monitor"; and (5) computer as a pre-programed control device utilizing multiple displays which tutor the learner in subject-matter content. For purposes of these remarks, I plan to restrict myself to the tutorial definition.

The first major barrier to the development of CAI is the hardware-software gap. In a sense, this problem resembles the chicken-egg controversy. Some experts maintain that the electronic and mechanical devices, together with their carefully tested operating systems, must be made available before

---

[1] Remarks prepared for American Management Association Meeting, Americana Hotel, New York City, August 12, 1966.

large scale content programs can be prepared on a meaningful basis. These specialists emphasize the necessity for compatibility between various systems in order that carefully constructed programs of instruction may receive widespread dissemination and testing. They claim that the equipment is the horse that must precede the proverbial cart.

An equally cogent argument is made by the group which believes a large number of courses should be developed first, and then the representatives of equipment manufacturers could examine these content materials and arrive at specifications for needed display and response gear. Both groups are correct from their own points of view, but the long-term development of CAI will probably be harmed by too rigid adherence to either extreme position.

A second major barrier to the development of CAI is the lack of experience and methodological know-how for constructing appropriate criterion measures useful in evaluating CAI courses. The ubiquitous, end-of-term achievement examination will just not do for measuring the yield from a sophisticated, individualized CAI program. The difficulty is that we have, in traditional instruction, become accustomed to offering a standard bill of fare to the learner, and we have based marks and "Brownie points" upon each learner's scale position relative to all other learners who were exposed to the same lectures, readings, stale jokes and class discussions. CAI, at its best, should offer a distinctly individualized course of instruction in which gaps in the learner's knowledge are filled in during the course by means of diagnostic and remedial sequence steps. Thus, it seems to be theoretically appropriate to ask the typical CAI learner to achieve mastery of the content as long as we allow him a reasonable amount of time. By the same reasoning, the learner with limited aptitude may be unable to finish the course, even though he is given an unrestricted time limit. The major variable for CAI programs under these postulates is a time score or a number-of-attempts score rather than an achievement score. For these reasons, CAI and conventional instruction may be fundamentally not comparable. Certainly, the typical end-of-term examination on which half of the learners miss half of the questions suggests, under CAI conditions, that there was something wrong with either the examination or the program which preceded it. If CAI lives up to its potential, it should be unnecessary to provide a special off-line immediate examination for any learner. If the examining is appropriately done at intervals throughout the program, then every learner should have achieved mastery of the content up to the limits of capacity.

A third barrier to CAI development is the inordinate amount of time required of the subject-matter author in preparing a course of instruction for CAI presentation. In a few subjects involving drill materials, it is possible to form a series of words, symbols, or algorithms into a standard sequence. These sequences, called "macros," are handy devices for building up a backlog of CAI displays in limited areas of instruction. But, most curriculum material is focused on objectives of instruction that go beyond simple associational learning. In our work with college level material at Penn State, we clearly recognize the "iceberg" analogy in CAI programs. When one student goes through a CAI programed sequence, typically his printout of the interaction between himself and the computer represents only about 12 to 20 per cent of the total stored program on that topic. In general, the more sophisticated the program in terms of alternatives and remedial opportunities, the more material is beneath the surface which the typical learner may never encounter.

Simpler, easier-to-use programing languages will help to alleviate this problem to some extent. But perhaps the most headway will be made by setting aside a small portion of a computer executive system which will enable an author to make "on-line" input of a block of material at the terminal, and to test that material immediately without going through a laborious compiling process. This capability is becoming available in some of the recently developed CAI systems. We are currently exploring other strategies for getting a maximum of finished product from authors for a minimum expenditure of their time. Some appear to be promising, but are as yet untried.

A fourth barrier to the development of CAI is our lack of knowledge concerning the appropriate "mix" between computer-mediated instruction and teacher-mediated components of instruction. In a sense the teaching machine movement, in its headlong rush to solve all the problems of education, failed to come to grips with the problem of the "mix." Should the learner spend 50 per cent of his time with the teacher and 50 per cent on the computer program? Can this ratio be 90-10 or 10-90 and still be effective? How do the various conceptions of CAI use influence the cost benefit analysis?

It seems entirely likely that the optimum recipe for intermingling CAI into existing forms of instruction will be different for different content, different learners and different situations, but the fundamental guidelines have not yet been derived either from empirical research or experience.

At Penn State during the recent spring term, we tried a field trial in three college courses in which CAI was designed to substitute for two of three regularly scheduled lectures per week. All students met with the instructor during the week's first period, and the CAI students scheduled themselves on the computer terminals for approximately two and one-half hours on the average during the remainder of the week. Other students attended the lecture-class discussion in the usual way. In a modern mathematics course, this arrangement worked well and the students functioned satisfactorily in the program. In two courses where heavy emphasis was placed on marks and on examination performance as the key factor in achieving marks, the students felt restricted by the pace of the CAI program. Many wanted to see all of the material to be covered in the examination so that they could organize a self-study program tailored to the emphasized examination.

These observations impressed upon us the fact that computer teaching programs are not as flexible for the student as existing textbooks and lectures. College students have certain expectations of the way in which courses are conducted, and they have rather firmly fixed stylized ways of responding to instructional "systems."

A fifth barrier to the orderly development of CAI is the lack of compatibility between computer systems which tends to retard the free exchange of programs of instruction developed in different laboratories and curriculum centers. In my opinion, not one of the three or four major operating systems in use today offers much advantage over the others; yet as far as I know, no two programs of different origin will "run" on the same computer. In our own Laboratory, we cannot operate courses which "ran" last year because we elected to "improve" the system, as it were.

A dimension of the compatibility problem is found in the controversy between single-purpose and multi-purpose computers for the CAI application. One leading manufacturer has recently announced an experimental class-sized configuration that will make it possible to operate up to thirty-two student stations simultaneously. This is a single purpose system that is not at this time compatible with any other known operational system, hence, teaching materials for the new system must be constructed from the beginning. Other manufacturers of hardware are apparently going to devise their own CAI operating systems in order to enhance the marketability of their equipment.

What mechanisms should be devised in order to insure compatibility of expensively produced programs on a variety of systems? The spectre of the teaching machine development, where there were at one time more different brands of machines than good programs, still hangs over us and we ought to demonstrate that we can learn from past mistakes, both our own and those of others.

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Student Performance Summaries for CAI Courses

Terry A. Bahn

This report on student records is divided into four sections:

1. Uses of student records
2. Requirements of good student records
3. How our student records meet these requirements
4. Means by which our student records are obtained

Uses of Student Records

At this stage of CAI development at Penn State, the primary use of student records is for obtaining data from experimental studies. However, in the future student records will be used for examining progress made by students and for evaluating course segments, e.g., if many students have a high error rate on a segment, perhaps that segment is too difficult and should be subdivided.

Requirements of Good Student Records

(1) Student records should be complete; that is to say, they should contain all pertinent information including course name, student number, restart address of segment, response, response latency, response category, and the condition of all author-manipulated counters at the time the segment was executed. Other things which are useful, though not quite so pertinent,

are date, time, response character count, number of trials of student on that segment, and a count of the unanticipated responses.

(2) Student records must be accurate. This is very important in all uses of such records. Stringent checks must be made to maintain high accuracy, especially on the more pertinent information. Unavoidable errors, e.g., those occurring at logging time in the Dean,[1] should be flagged to indicate that they are in error so that CAI investigators may take the condition into account.

(3) A method of obtaining a statistical summary must be available in order to facilitate the discovery of trends and deviations in performance and to facilitate segment evaluation and study of student progress.

(4) Another important requirement is economy in terms of money and time. While monetary economy is a self-evident requirement, time economy may need some explanation. A one week turn-around would be desirable between the performance of the last learner in a study group and the availability of a student record summary of all learners in the group.

(5) A final requirement of student records is flexibility. Student records should have the ability to adapt to investigator needs in relation to grouping order, pooling, and the suppression of information extraneous to author's purposes.

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[1] The control and monitoring system for IBM 1410 CAI system.

Student Records Program at Penn State

How well does the student records program at Penn State meet the requirements of instruction?

Completeness. The student records are quite complete, including all of the items of information mentioned on the previous page (see APPENDIX A-5, p. 112).

Accuracy. The student records are reasonably accurate including some flagging of log errors. However, there is a definite need to check the Dean in order to correct log errors in the response categories.

Statistical Summary. The statistical summary of student records is complete and flexible enough for most author uses. The summary includes student number, sequence number, attempts, mean latency, standard deviation of the latency, and frequency of correct response. The author has a choice of one of four methods (see APPENDIX A, p. 107) of statistical summary:

1. Students within sequence numbers, all separate (p. 108)
2. Sequence numbers within students, all separate (p. 109)
3. Students separate, sequence numbers pooled (p. 110)
4. Sequence numbers separate, students pooled (p. 111)

Since frequency of correct response will always be 1 when both students and sequence numbers are taken separately, it is not listed in subroutines 1) and 2).

If students or questions are pooled, the author can specify an error criterion. If the error rate exceeds this criterion, the entry is flagged with the symbol *T* in the student record printout. This procedure helps the author to identify high or low error rate frames and students.

Economy. Student records for a typical course segment of 75 frames taken by 75 students costs approximately $50 to $75 in computer time. This figure includes a statistical summary.

Time - Student records for a typical course segment taken on-line by 10-30 students can be gathered in about one to three weeks from the request date. Unfortunately, this turn-around time is too long for instruction where more immediate feedback to teacher and learner is desirable. We are presently seeking ways to shorten this turn-around time.

Flexibility. The student records program has sacrificed some flexibility in order to increase efficiency and economy. However, they seem to be sufficient for present needs and can be adapted to future needs as the occasion arises.

Methods Used for Obtaining Student Records Listing

Two different machines and three different programs are used to obtain the student records listing. Program I, used on an IBM 1401, edits a 339 character log record to a 195 character record. Program II is the IBM sort/merge program operated on an IBM 7074. This program sorts records according to course name, student, sequence number, time and anything else an author may desire. Finally, Program III lists the student records according to requested course, students and sequence numbers (restart addresses) and punches cards containing course name, student number, sequence number, date, latency, response character count, the X1 and X2 counters, response category, unknown response count, clock and trials. Program III operates on the IBM 1401 and allows the printing of certain information to be suppressed if so desired. All three of these programs have facilities for input/output error detection and Programs I and III have facilities for correcting such errors.

Statistical Summary

The statistical summary is obtained by means of a program with four subroutines written in D.A.F.T. (Dual Autocoder-Fortran Translator) which operates on the IBM 7074. This program uses the cards punched by Program III above for obtaining its data.

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Some Comments Concerning Efficiency in the Preparation of Materials for Computer-Assisted Instruction

David Alan Gilman

Several authors (Dick, 1965; Silberman and Coulson, 1962; Gentile, 1966) have assessed the difficulty and amount of time required for the preparation of instructional materials for computer-assisted instruction. Time estimates vary due to the fact that different standards of comparison are used. Silberman and Coulson (1962) estimate that preparation of a two-hour lesson may take several months. Gentile (1966) finds agreement among professional programers that only a few good frames can be written in a day. The difficulty of programing a lesson (in a subject matter familiar to a teacher) is compounded with the difficulty of writing the program in a form acceptable to a computer. Gentile feels that this combination is too much to ask of a course author.

In the experience of this author, under optimum conditions an experienced author-programer can hope for no better than a 1/40 ratio of instructional time to preparation time. Comparison of this ratio to that of other experienced authors indicate that this ratio is considerably better than theirs, with typical figures being 1/70 or 1/100.

There exist several points of view concerning the best method for preparing programmed material for computer-assisted instruction. These points of view are evident in the philosophies of the various languages available for programming materials for different computer systems.

The level of strategy required in a course may dictate the type of programming that is to be done. At the simplest level of computer language are languages such as PLATO[1] (Bitzer, Braunfeld, and Lichtenberger, 1962) which require only that the author enter his text and rules for evaluating his answers. The computer has been programmed to accept the text and the author does not need to learn the computer language, but rather learns a few procedural rules for preparation of course materials. The Coursewriter language (Maher, 1964) is an example of a second level of difficulty. Coursewriter requires that the author program his pattern of instruction in a language which might be described as relatively simple, but the use of the language becomes complex as the author's strategy becomes more and more involved. The highest level of programming technique is required by the author who writes his own computer program in machine language to carry out instructional strategies. This allows the use of the full capability of the computer, but necessitates a high level of competence in computer programming as well as in instructional strategy.

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[1] Acronymn for Programmed Logic for Automatic Teaching Operations.

The Coursewriter language, developed by IBM scientists, has been written in such a way that the course author can use practically any strategy he desires provided he is skilled enough to program it. The use of such a language requires that the author be familiar with the language and know a number of programming tricks in order that he can accomplish the desired objectives. Some attempt has been made to make the Coursewriter language compatible with natural language, but if an author is to use a rather complex instructional strategy, he will need to know how to program this strategy. The Planit[1] language (Feingold and Frye, 1966), put together at Systems Development Corporation, represents an attempt to use the computer to assist the course author by informing the author at each step in the programming as to what type of statement he should program next. Thus if the next statement in the program should be a question, the computer will type "sq" to the author, which indicates that the author should now specify the question. A message of "sa" typed to the author indicates that the author should now specify the anticipated answer. In essence, Planit provides guidance to the author in programing his course.

While the Coursewriter approach represents a more flexible approach and therefore an approach which can be more fully utilized to present complex learning situations, much can be said for the greater efficiency in the method employed in Planit. The question which must be answered in the choice of a language for a computer assisted instruction system is, "How complex are the instructional strategies going to be for a given curriculum?"

---

[1] Acronym for Programming Language for Interactive Teaching.

The complexity of instructional strategies ranges from using the computer as a tool to present paired associates learning materials to using the computer to teach concepts in a manner akin to the way a classroom teacher or tutor might present them. A language limited to the preparation of materials for paired associates learning would not be particularly valuable, since there are many devices such as the Gerbrands memory drum which can efficiently accomplish the same objectives at considerably reduced costs and with much less effort required from the experimenter.

At the other extreme, it is not an efficient use of a teacher's time to code complex computer programs. Even if programing were as easy as writing a book, it would be questionable to expect a large number of classroom teachers to have the time to write good books. Bugelski (1964) predicts that program writing will ultimately be left to professional programers who will work with subject matter consultants.

Several alternatives to these two extremes are available and can readily be put to use. Each of these involve the use of a fairly simple language, such as Coursewriter and the writing of questions, anticipated responses, and appropriate feedback for each frame by an author familiar with the subject matter.

The essence of the solution to the problem of the great length of time and great amount of effort required for the preparation of materials for computer-assisted instruction lies in the ability of the language to accomplish complex strategy without the accompanying burdens of complex program coding.

Some alternatives to having an author program course material are the use of (1) author-course programmer teams, (2) a programming workbook, (3) an automatic author prompting device, and (4) macro programs or standard sequences of program options into which a variety of different text materials can be fitted. Each of these have been tried with some degree of success by the Penn State CAI Laboratory and each are being considered for further development.

Each method herein described is capable of providing fairly sophisticated strategies of instruction for a course author.

Author-Coder Teams. The use of author-coder teams has been the most evident and probably the most widely used method of increasing programming efficiency which we have employed at Penn State. This method is fairly simple. The author first plans his instructional strategy and brings the material to a coder. It is not necessary that the coder be skilled in languages other than Coursewriter, since Coursewriter should be able to accomplish most strategies planned by the author. The coder can approach the problem in any of two ways. First, he can instruct the author as to how to program the material and give him step-by-step directions for preparing the course, or he can do the program coding himself.

The question which arises at this point is the amount of skill and training required of the coder. The CAI Laboratory at Florida State University, for example, employs clerical-technical personnel as consultant-programmers. The author prepares as much of the material as he wishes and then turns the material over to a technician who finishes the programming. It is fairly easy to train a technician to become a skillful coder. However, care must be taken to insure that the author has control over the programming of his course and that when the technician utilizes special programming techniques that these techniques do not change the author's intended teaching strategies.

A second point of view is that the coder should also be a skilled instructor or psychologist so that he can evaluate the author's strategy and make suggestions as to how the course could be best taught. The difficulty in this approach is that it would probably be rather difficult to find such a skilled person who would be willing to confine his activities to course coding.

A third approach, utilized we understand by the computer-assisted instruction project of the Westinghouse Corporation, is using a skilled professional programmer to prepare the author's program in a computer language such as Autocoder or SPS. The greatest difficulty in this approach is that the author, because of his lack of understanding of the computer language, becomes far removed from the course preparation and is unable to contribute course improvements.

In summary, the use of an author-coder team can improve the efficiency of course preparation. However, there exists a danger that the author may lose control of course strategy and may also lose some flexibility if he does not understand what the coder can do with the author language.

Programming Workbook. This method of improving efficiency involves the preparation of a standard instructional frame or a series of instructional frames on a form in such a way that the author needs only to complete a few blanks in order to accomplish the programming task.

The difficulty in using this method is that the author is limited to one (or a few) instructional strategies in any course. Figure 1.1 shows a typical series of Coursewriter statements arranged in a programming workbook. The author needs only to prepare the appropriate instructional messages, questions, anticipated responses, and feedback, and write them in the blank spaces. The course can then be punched on cards in the regular manner by a technician.

```
ac __ __   rd                                       (author specifies label name)
           ty   ___________________________________(author specifies instructional
                ___________________________________message)____________________
           ld   0//s3
ac __ __   qu   ___________________________________(author specifies question)
           nx
           ad   x0//x2
           fn   _______________                     (author specifies type of processing)
           ca   _________________________         . (author specifies correct answer)
           fn   sb///stl//a0///sayright             (feedback for correct response)
           ld   1//s3
           ad   1//c1
           br   ac-__ __//s3//1                     (students who respond correctly are
                                                    branched)
           unl  ___________________________________(feedback for responses which are in-
                                                    correct)
           un2  ___________________________________________________
ac __ __   qu   ___________________________________(author specifies remedial question)
           nx
           ad   x0//x2
           fn   _______________                     (author specifies type of processing)
           ca_  ___________________________________(author specifies correct answer)
           fn   sb///stl//a0///thatsbetter          (feedback for correct response)
           ld   1//c2
           ld   1//s3
           br   ac __ __//s3//1                     (students who respond correctly are
                                                    branched)
           un   ___________________________________________________
           un   ___________________________________________________
           br   ac __ __                            (students who reach this point
                                                    in the program do not understand
                                                    and are branched to more remedial
                                                    work)
```

Fig. 1.1 Sample page from a programming workbook.

Programming workbooks provide a simple and direct way of preparing course materials. However, the courses prepared by this method may become dull and repetitious for the student since the same type of questions are presented in each frame.

Automatic Author Prompting Device. IBM has recently marketed a device called the Magnetic Tape "Selectric" Typewriter. This machine allows a sequence to be stored on a magnetic tape and a typist can manually insert changes, additions or deletions in the program. A programming workbook could be stored on the tape and utilized in such a way that a set of options could be provided the author at every step and the author could provide the text of these statements by simply typing them. The program and the author's statements are then stored on tape. Errors can be corrected by erasing the tape in the area where the error occurred and by retyping the correction. The revised course is then stored on the tape.

It should be possible to connect the Magnetic Tape "Selectric" Typewriter to a card punch in such a way that cards containing the course material can be punched for computer input automatically after the last revision is made.

The disadvantages of this method of preparation are similar to those of the programming workbook. In fact this method is, essentially, a mechanized programming workbook. In addition some authors may experience difficulty in learning to operate the equipment.

A Macro Program. A macro program is a sequence of pre-programmed options into which text material may be fitted. Some of the inadequacies of the programming workbook approach can be overcome if one utilizes a prepared program to accomplish any of several strategies. In using a macro program such as the one developed at Penn State, the author merely types a one digit number (or a combination of one digit numbers) to indicate the type of strategy he wishes to use for a particular question frame. After typing the number or numbers, the author merely needs to specify the feedback which goes with each of several responses.

The options contained in a macro program designed and in operation at Penn State and their corresponding code numbers are indicated below:

1. No feedback
2. Feedback of "wrong" if the response is incorrect
3. Feedback of why the student's response is incorrect
4. Feedback of "correct" if the student's response is correct
5. Feedback of why the student's response is correct
6. Feedback containing a statement of the correct response
7. Feedback of why the correct response is correct
8. Repeat of question if response is incorrect
9. Repeat of all questions missed in program until all frames are answered correctly

The author needs only to program a series of integers to indicate his strategy. An author wishing to have feedback of "wrong" when the student's response was incorrect, a feedback of why the student's response was incorrect, and repeat of the question if the response is incorrect would simply program 238. The order of the integers is unimportant. Any combinations of alternatives 2 through 9 is possible, but choice 1 is not compatible with the remainder of the choices. Appropriate feedback for each of the responses must also be listed by the author. This is all the programming the author needs to do.

Other improvements are possible. The author may choose to use feedback indicating a correct answer from a series of potentially reinforcing comments such as "right," "correct," "very good," or "hot dog." These comments may be chosen randomly from a prepared list by use of a subroutine.

The original macro programs may be prepared by any programmer skilled in the use of Coursewriter. Since the macro itself is written in Coursewriter, some authors may use the macro while other authors may continue to do their own programming in Coursewriter.

Figure 1.2 indicates a flow chart containing the options available to an author who uses the macro described in the previous paragraphs. Figure 1.3 indicates the programming steps used by the course author. Such a programming arrangement enables an author who knows nothing of the programming language to prepare courses which utilize rather complex strategy. Improvements or new strategies may be programmed by providing changes in the macro.

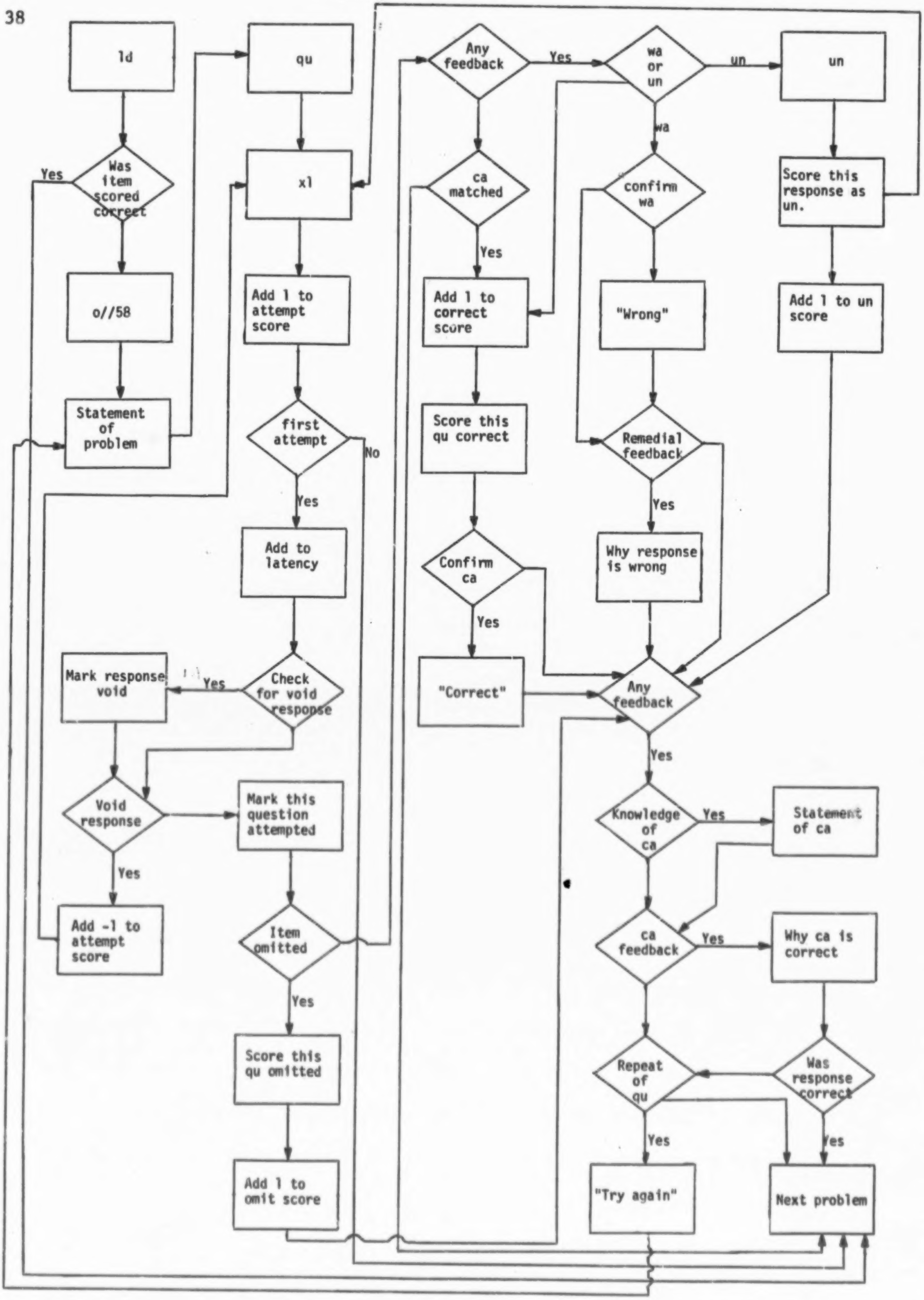
ld
Was item scored correct
Yes
o//58
Statement of problem
qu
xl
Add 1 to attempt score
first attempt
No
Yes
Add to latency
Check for void response
Yes
Mark response void
Void response
Yes
Add -1 to attempt score
Mark this question attempted
Item omitted
Yes
Score this qu omitted
Add 1 to omit score
Any feedback
Yes
ca matched
Yes
Add 1 to correct score
Score this qu correct
Confirm ca
Yes
"Correct"
wa or un
un
wa
confirm wa
"Wrong"
Remedial feedback
Yes
Why response is wrong
un
Score this response as un.
Add 1 to un score
Any feedback
Yes
Knowledge of ca
Yes
Statement of ca
ca feedback
Yes
Why ca is correct
Repeat of qu
Yes
"Try again"
Was response correct
Yes
Next problem

Fig. 1.2. Programming options available in each frame for authors using macro techniques.

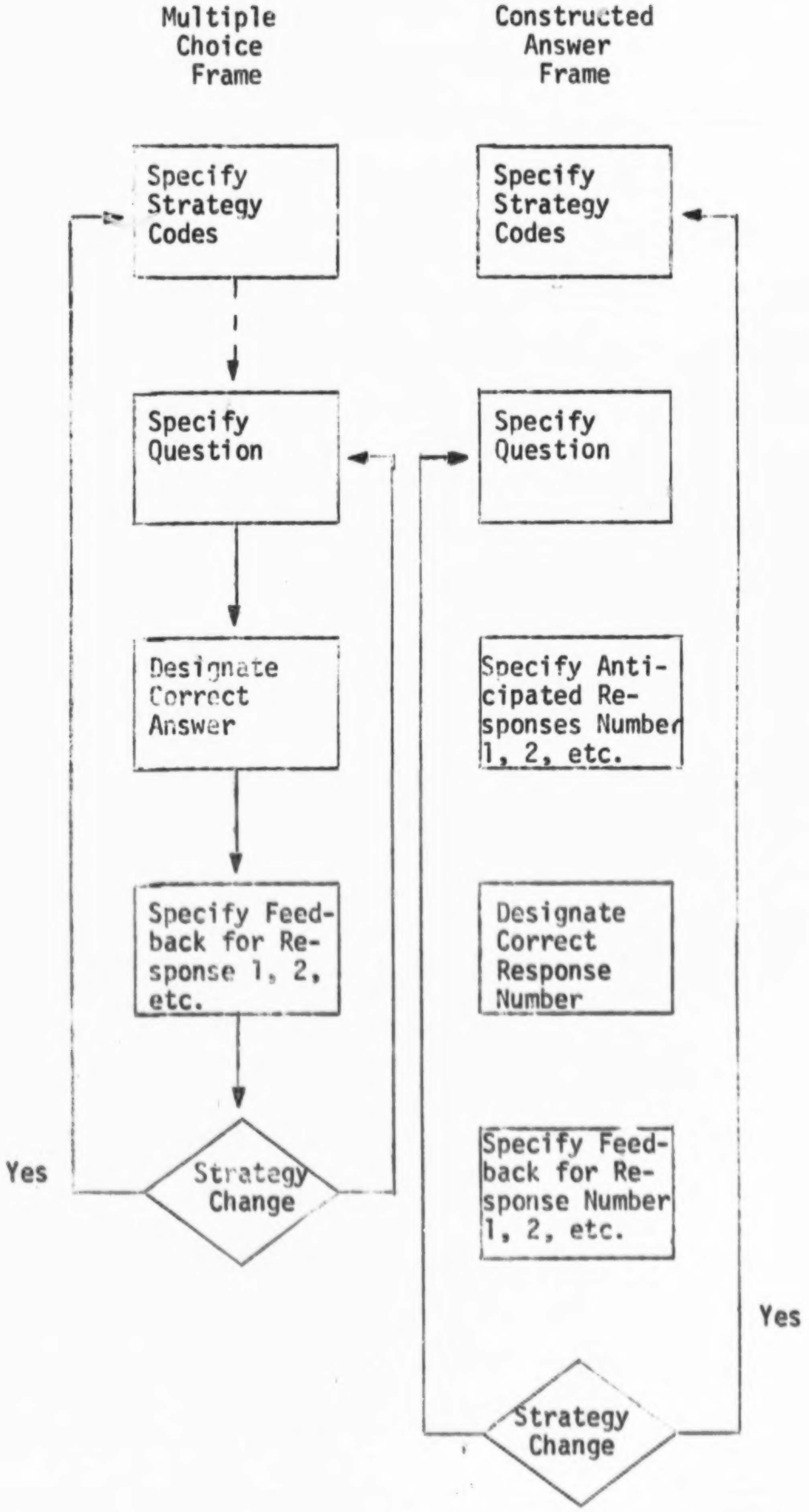
Multiple Choice Frame
Constructed Answer Frame
Specify Strategy Codes
Specify Question
Designate Correct Answer
Specify Feed-back for Re-sponse 1, 2, etc.
Strategy Change
Yes
Specify Strategy Codes
Specify Question
Specify Anti-cipated Re-sponses Number 1, 2, etc.
Designate Correct Response Number
Specify Feed-back for Re-sponse Number 1, 2, etc.
Strategy Change
Yes

Fig. 1.3. Steps followed by author using a macro program.

Such a plan is ideal for the programming of multiple choice programs in the intrinsic programming style recommended by Crowder (1962). Also, through the use of the Coursewriter edit function, constructed responses can be made equivalent to numbers. These numbers may then be used to represent the response alternatives. Thus, the first anticipated response may be made equivalent to a 1, the second anticipated response may be made equivalent to a 2, etc. By using this technique, the macro may be used for constructed response programs as well as for multiple choice programs.

Conclusion

There are several methods for improving the efficiency in the preparation of instructional materials for computer-assisted instruction. Among the methods discussed were the author-coder team, the use of programming workbooks, an automatic author prompting device, and the macro program. It is probably asking too much of an author to expect him to prepare instructional materials and also program them for computer presentation.

Author-coder teams represent increased efficiency. The coder may serve as a consultant or may actually do the programming for the author. The use of programming workbooks is another possibility, although preparation of materials by this method limits versatility of instructional strategy. The same difficulty is true of an automatic author prompting device such as a Magnetic Tape "Selectric" Typewriter. This device may also be rather difficult for authors to use.

The use of a macro program represents a highly efficient method of course preparation. By using a macro program, it is possible to have a natural language program without sacrificing the versatility of the programming language. Many strategy variations may be utilized simply with the use of a macro program. Eventually, CAI programming should be no more different than preparing a well-thought through lesson for the classroom.

It should be emphasized that each of these methods is relatively inexpensive when compared with the on-line costs for direct author input of material in an interpretative mode. These methods may represent considerable savings when increased efficiency in the use of the author's time is considered.

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CHAPTER II

ENGINEERING SCIENCE

David Alan Gilman and Robert Igo

The engineering science course is being developed in such a way that it will serve a dual purpose. First, and most important, the course segments are being programmed to serve as material for research studies. Second, the course segments are being combined to form a comprehensive curriculum in engineering science.

Primary emphasis has been given to the development of materials suitable for the teaching of the basic skills for the engineering technician. Among these are the use of significant figures, measurement, working with units, the metric system, and the use of scientific notation. Several versions of course segments in these areas have been prepared and are available for the use of experimenters. Also, materials have been prepared in the areas of optics, heat and thermodynamics, atomic structure, electrostatics, and electronics. The Engineering Science course segments now total approximately 23 1/2 hours of instruction.

One area currently under development is a simulated physics laboratory suitable for technical education students. The goal of the simulated laboratory is to take advantage of the highly motivating aspects of "guided discovery" learning and inquiry methods. Experiences are planned which will enable students to demonstrate their knowledge of the various elements which go into the solution of a problem and to query the computer for those items of information which they do not possess.

During the past six months, two studies have been conducted. Each of the studies involved teaching physics to technical education students. The first study was a comparison of three branching techniques in teaching a programed sequence. The second attempted to compare the effectiveness of differing the verbal content of programs for students of high and low verbal ability.

Articles describing the computer-assisted instruction project in technical education at Penn State appeared in the September 1966 issue of Technical Education News and the November 1966 issue of School Shop (see Appendix B, p.115). An article describing a study in engineering science has been accepted for publication by the Journal of Educational Research.

The three examples following are instructional sequences taken from course segments in engineering science. These sequences illustrate several different programing strategies, as shown in the accompanying flowchart for each example. An understanding of the role of each of the mnemonic codes or operands can be obtained by referring to Chapter 1, page 4, of this report.

Example 1

Segment: Introduction to Physics
Institution: Penn State
Author: D. Gilman

The program first checks to determine whether or not the student has given the words "matter" and "energy" in his answer. If the answer does not contain both words, it is tested for the presence of either word. If "matter" or "energy" is found in the answer, the student is told he is partly correct and directed to type a complete answer. The un, which tells the student the answer is typed only if the student's response contains neither "matter" nor "energy."

This relatively simple coding method gives the student who is on the right track the opportunity to improve his answer. There are three different treatments provided for the completely correct, partly correct, and completely wrong responses.

The program is written so that the students' responses will be typed in red and the computer messages will be typed in black.

```
LABEL     OP     TEXT
          qu     What is physics the study of?   (PreA)*
          nx
          fn     ed//#// // //s
          fn     kw//2//c2
          ca     ,matter,energy
          ty     Correct.
```

---

*Programed so that automatic ribbon shift from black to red occurs and student's response will be typed in red.

```
LABEL     OP     TEXT
          nx
          br     wrong//c2//1//1
          ty     You are partly correct.  Type the complete
                 answer.   (PreA)
          br     x10
wrong     un     Your answer is not correct.  Physics is the
                 study of matter and energy.  Type the correct
                 answer to the question.   (PreA)
          rd
```

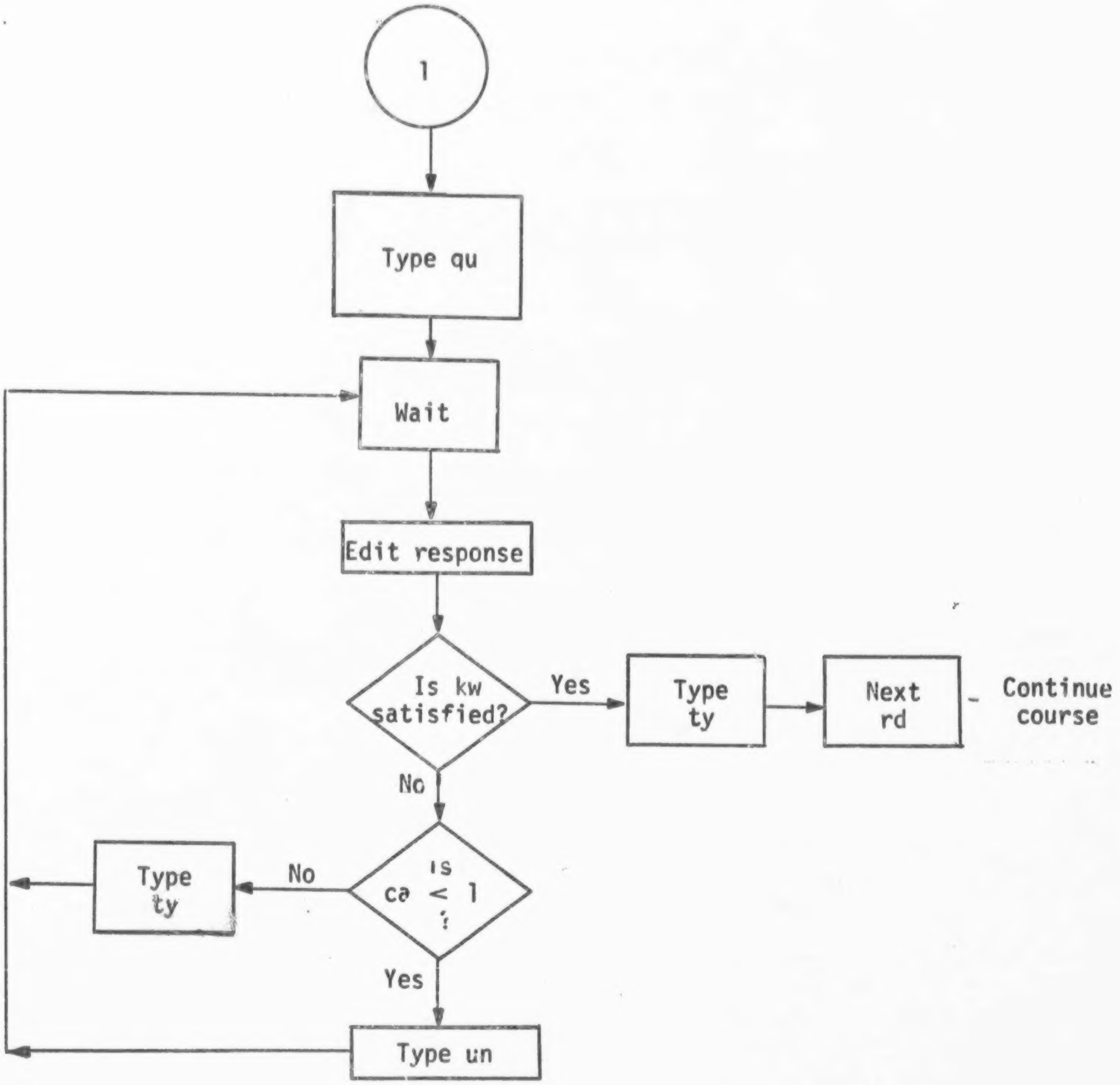
1
Type qu
Wait
Edit response
Is kw satisfied?
Yes
Type ty
Next rd
Continue course
No
Is ca < 1 ?
No
Type ty
Yes
Type un

Fig. 2.1. Flowchart for Example 1 (Introduction to Physics)

Example 2

Segment: Atomic Energy

Institution: Penn State

Author: D. Gilman

The author programs the computer to generate a random two-digit number by the function "irand," and then uses that number to pose a problem to the student. The "lim" function is used to check the student's answer. By using the "lim" function it is possible to store the contents of the counter containing the random number as the correct answer. He is looped through the same sequence, getting a newly generated number each time, until he is correct on one.

```
LABEL   OP[1]  TEXT
a-80    rd
        fn     irand//c2//c2
        br     a-80//c2//e//0
        ty     How many protons would there be in an atom
               having ,,
        fn     dc//c2
        qu     ,, electrons?
        nx
```

---

[1] Refer to Chapter 1, page 4, for an explanation of mnemonic codes and operands characteristic of Coursewriter language.

```
          fn     ed//$//s
          fn     lim//1//c3
          ca     1//99
          br     a-80-1//c2//ne//c3
          ty     Right.  They are equal.
a-80-1    un     They should be equal.  Try another problem.
          br     a-80
a-84      rd
```

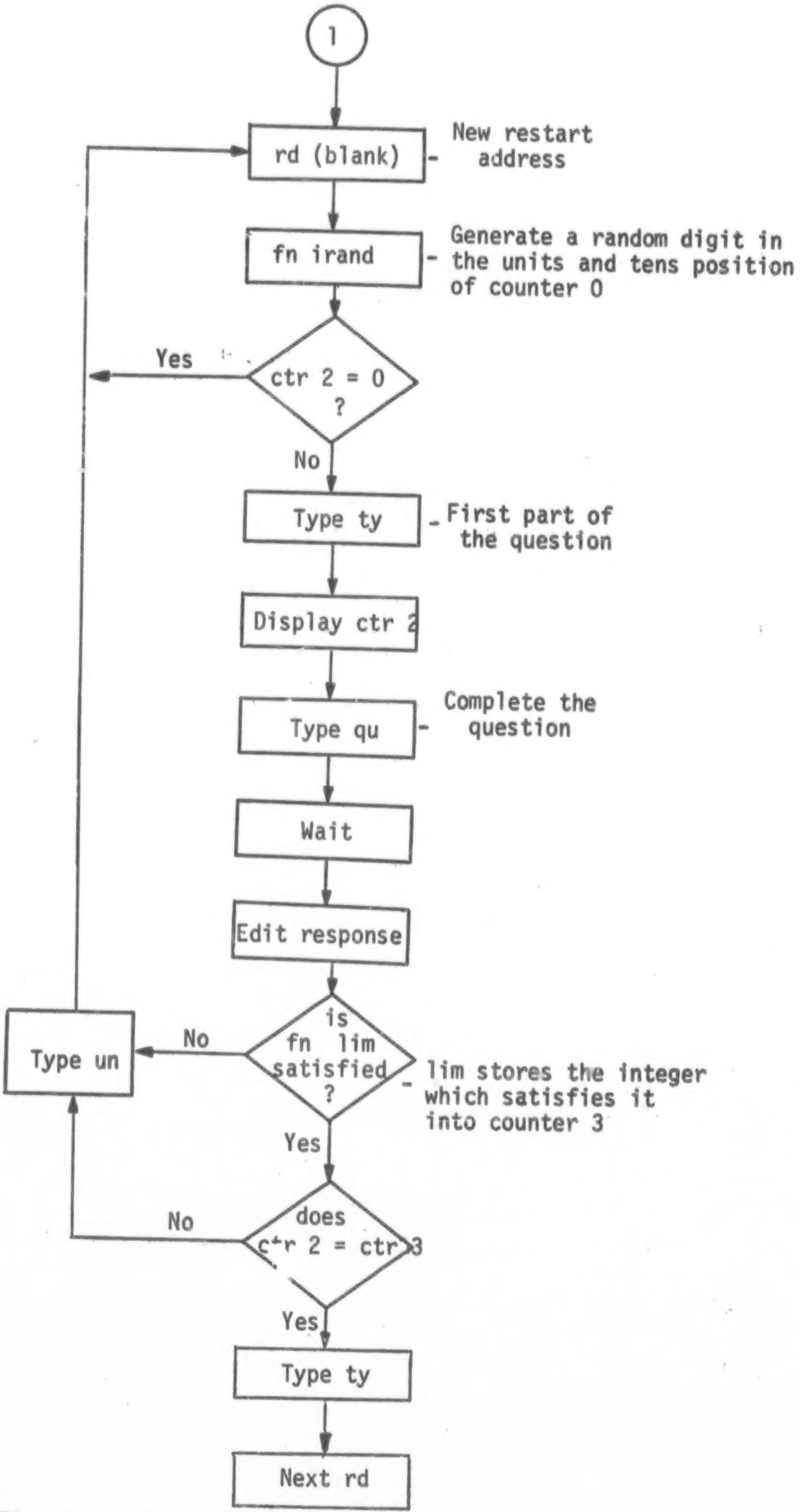
1
rd (blank)
New restart address
fn irand
Generate a random digit in the units and tens position of counter 0
Yes
ctr 2 = 0 ?
No
Type ty
First part of the question
Display ctr 2
Type qu
Complete the question
Wait
Edit response
No
is fn lim satisfied ?
Type un
lim stores the integer which satisfies it into counter 3
Yes
No
does ctr 2 = ctr 3
Yes
Type ty
Next rd

Fig. 2.2. Flowchart for Example 2 (Atomic Energy)

Example 3

Segment: Atomic Energy

Institution: Penn State

Author: D. Gilman

The author wants to accumulate the student's response data in this question and type out his total response time to the student. The author first clears counter x1. He then inserts a blank *rd* before the question so the counter will not be re-cleared if the student takes more than one session to complete the question.

Each time the student answers the question, his response time (from when he received the PROCEED light until he entered the EOB signal) is added to x1. His answer is then processed. The student is told whether he is correct or wrong and how many seconds he has spent on the question.

```
LABEL     OP[1]   TEXT
          rd
          fp1     35
          ld      0//x1
          rd
          qu      Examine the slide.  What is the atomic number
                  of sodium?
```

---

[1] Refer to Chapter 1, page 4,for an explanation of mnemonic codes and operands characteristic of *Coursewriter* language.

```
LABEL     OP     TEXT
          nx
          ad     x0//x1
          fn     lim
          ca     28//23
          br     okay
          nx
          fn     ed//#// // //s//-
          fn     kw//1
          ca     ,twentythree
okay      ty     Correct.  It took you  ,,
          fn     dc//x1//-2
          ty     ,,  seconds to answer the question correctly.
          wa     go
          ty     23
          un     Wrong.  You have now spent  ,,
          fn     dc//x1//-2
          ty     ,,  seconds trying to answer this question.
          rd
```

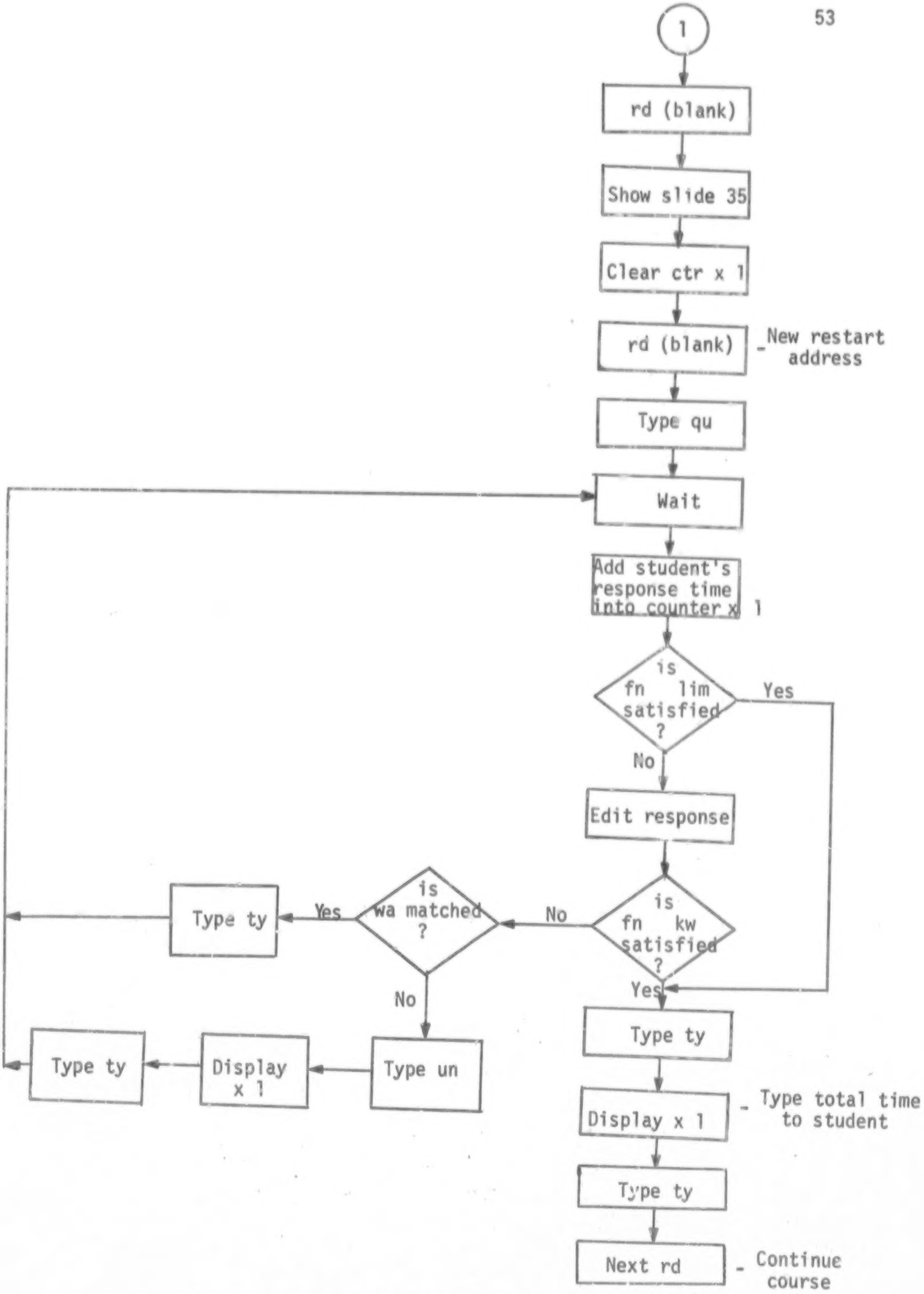
1
rd (blank)
Show slide 35
Clear ctr x 1
rd (blank)
New restart address
Type qu
Wait
Add student's response time into counter x 1
is fn lim satisfied ?
Yes
No
Edit response
is fn kw satisfied ?
No
Yes
is wa matched ?
Yes
No
Type ty
Type un
Display x 1
Type ty
Type ty
Display x 1
Type total time to student
Type ty
Next rd
Continue course

Fig. 2.3. Flowchart for Example 3 (Atomic Energy)

CHAPTER III

TECHNICAL MATHEMATICS

David Alan Gilman
and
Nancy Ann Harvilchuck

Computer-assisted instruction in technical mathematics has utilized for its foundation the principles emphasized in numerous technical mathematics texts in current use. These texts, together with the guidelines suggested in Curricula for Six Technologies, by Arnold and Schill (1965), have been used extensively in the planning, preparation, and evaluation of course material.

During the last six months, the major activities of the technical mathematics program have been the preparation of course material and the planning of research studies.

A total of 14 mathematics course segments, approximately twenty hours of student instruction time, have been developed at Penn State to date. One recently developed course considers logarithms and exponents. The student first reviews exponential notation and then is introduced to the concept of logarithms. After some practice in the manipulation of logarithms, the student begins to solve simple problems. He then utilizes his knowledge to work problems of a practical nature. Since the program uses static displays, the student may refer to previous examples at any time.

A sample of the logarithm program follows:

Sample of Logarithm Program

OP[1]	TEXT
qu	7. Here's a tricky one. $a^4 \div a^4 =$ _____ Solve this using the division law for exponents
nx	
fn	kw//1
wa	`$1$one`
ty	Your answer is correct but what is it in exponential form? ($a^?$)
nx	
fn	kw//1
ca	$\$a0\$a^0\$A0\$A^0$
	(The student has been told to type a0 (azero) for a^0.)
ty	Correct. Whenever you divide one number by itself you get one. So by definition $a^0 = 1$.
un	$a^4 \div a^4 = a^{4-4} = a^0$ Type a0.

The program tries to help the student solve examples as illustrated below:

qu	16. Example: To express 537 in standard notation 1. First write 5.37 2. To obtain 537, we must multiply 5.37 by ____?

---

[1] Refer to Chapter 1, page 4, for an explanation of mnemonic codes and operands characteristic of *Coursewriter* language.

```
nx
fn        kw//1
ca        $hundred$100 $L00
ty        Good.
un        5.37 x _____ = 537.
ad        1//cl
un        You must multiply by 100.  Type 100.
ad        1//cl
qu        17.  100 can be expressed as 10 squared or 10 to
               what power?
nx
fn        kw//1
ca        $ 2 $two$econd
ty        Good.  The final result is 4.37^2 x 10 in standard
          notation.
un        10^0 = 1, 10^1 = 10, 10^2 = 100, etc.  Try again.
          What power is needed?
ad        1//cl
un        The answer is 2.  Type 2.
ad        1//cl
```

After some practice with standard notation, the student begins solving simple problems.

```
qu        33.  Log to the base 9 of 3 can be written as
               log 3 = n.  Find n.
```

nx

fn kwo//3

ca $1$/$2

ty Good

un This is tricky. $9^n = 3$. What's n?

un Hint: n is less than 1, but greater than 0. Try again.

un n = 1/2. Type 1/2.

By the end of the program, the student is ready for complex practical problems as illustrated below.

qu The weight w in pounds which will crush a solid cylindrical cast iron column is given by the formula

$$w = 98,920 \quad \frac{d^{3.55}}{l^{1.5}}$$

where d is the diameter in inches and l is the length in feet. What weight will crush a cast iron column 8 ft. long and 5.2 inches in diameter? (3.55 and 1.5 are exponents)

nx

fn kw//1

ca $1,004,000 $1,004,000 $1,004.000.$1004000.

ty Correct. Now for the last problem.

un Wrong. Recheck your work and try again.

un Wrong. Log 2 = log 98,920 + 3.55 log d -1.5 log l.

un Log 2 = 6.00173. Find w.

Research studies being planned involve comparisons of various media for instruction and drill in mathematics and the use of several varieties of feedback to teach mathematics. Two studies are being planned which will compare the efficiency of teaching a student by an instructional sequence which the student selects, with an instructional sequence selected by the course author. Considerable emphasis is also being given to the appropriate amount of verbal content that a program should contain in order for it to teach most effectively.

Perhaps the most significant aspect of computer-assisted instruction is its branching and decision-making capability. The computer has the potential to branch on the basis of any of several predictors (i.e., error rate, response latency, mental age, attitude scores, and other variables). Our research will attempt to identify predictors which correlate differentially with performance in different instructional treatments. From this information it will be possible to develop branching decisions based on empirically validated predictors. Cut-off scores can be established so that students are branched to instructional treatments which optimize learning.

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CHAPTER IV

COMMUNICATION SKILLS

Harriett A. Hogan and Helen L. K. Farr

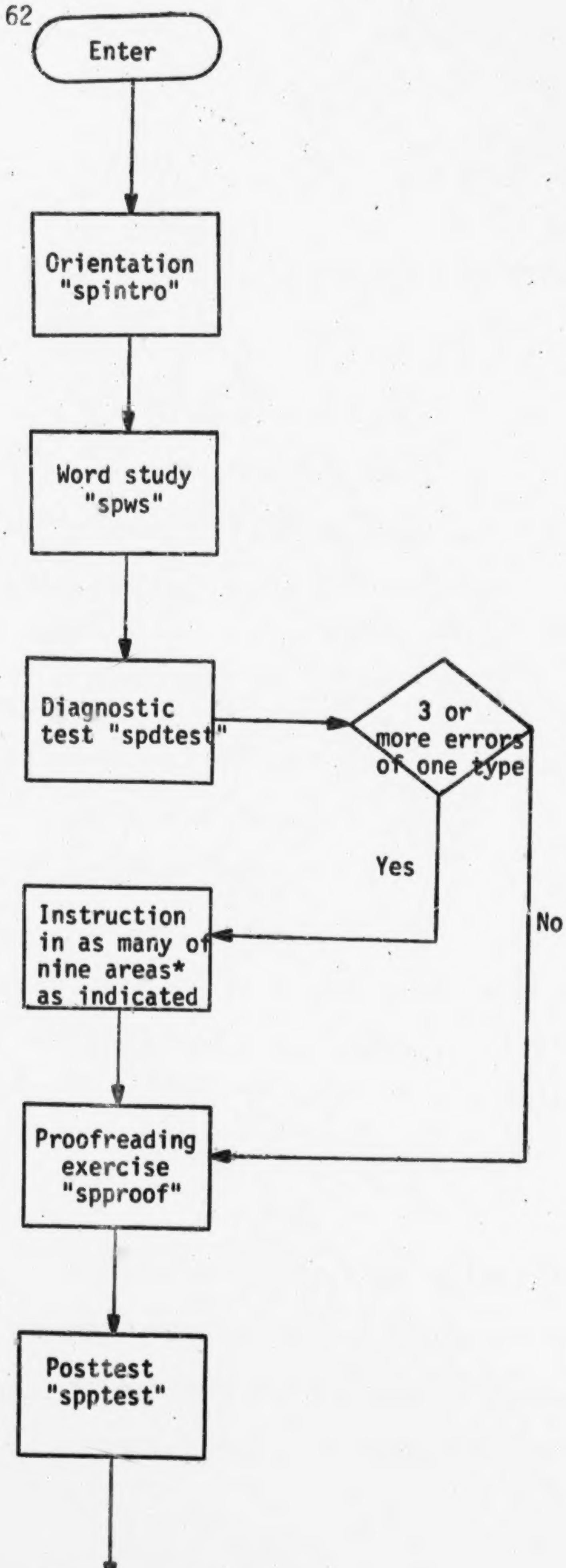
Summary of Activities

During the third six-month period of the project, the final remedial spelling segments of the communication skills programs were completed, put on the CAI system, revised, and then submitted to a field trial. A total of 14 spelling segments was available for use.

The purposes of the spelling programs are to evaluate the spelling competencies of students preparing to be technicians and to provide remedial instruction in nine areas of spelling as needed by each individual student. Major emphasis in each spelling program is directed toward the utilization of the decision-making capacity of the computer to individualize instruction and toward the optimum use of the audio-visual equipment associated with the computer terminals.

In Figure 4.1 a flow diagram of the complete spelling program is shown.

The program includes an orientation to the IBM Selectric typewriter, tape recorder and photographic slide computer outputs, a word study unit, the diagnostic test, nine remedial segments, a proofreading exercise and a spelling achievement test.


Enter
Orientation "spintro"
Word study "spws"
Diagnostic test "spdtest"
3 or more errors of one type
Yes
No
Instruction in as many of nine areas* as indicated
Proofreading exercise "spproof"
Posttest "spptest"
Stop

*Nine Instructional Areas:

1. sppl - plurals
2. spsuffix - prefixes and suffixes
3. spe - final e words
4. spi-e - words containing ie combination
5. spsyl - studying words by syllables
6. spcomp - contractions and compound words
7. spdiscr - similar words
8. sphom - homonyms
9. spdemon - demon words

Fig. 4.1. Flow diagram of CAI spelling program.

The word study unit emphasizes the importance of systematic word study in the improvement of spelling. Students are encouraged to look at each word, pronounce it and then write it. Instruction in dividing words into syllables is included. Word study also includes examining words for "trouble spots" such as silent letters, difficult vowel combinations, and unphonetic sounds.

The diagnostic test is used to evaluate each student's spelling performance in nine problem areas. Five items in each of the nine areas are included in the 37 word diagnostic test. This is accomplished by using some of the same words for more than one purpose. For example, in the word perceive, if the first syllable is spelled incorrectly, it is tallied as a prefix-suffix error; if the *ei* combination is reversed, an *ei-ie* error is tallied. If a student makes two or more errors of one type he is branched to the appropriate remedial program. Unanticipated responses in either syllable are tallied as errors which will branch the student to the remedial program.

The objectives of the proofreading unit are to emphasize the importance of proofreading written work and to improve the spelling of words in context. A segment of a technical report such as might be prepared by a technician is displayed to the student and he identifies and corrects misspelled words.

The achievement test, like the diagnostic test, is made up of words containing nine types of spelling problems (Appendix C, p.127). Difficulty of the two tests is equated so that change scores from the diagnostic test to the achievement test can be obtained.

Words used throughout the spelling program are selected from lists of most commonly used words and lists of technical words. The selection of words and the context in which they are used are intended to interest the technical student and to illustrate to him how spelling may be an occupational skill important to him in his work as well as in general usage.

In the fall, the two staff members working on communication skills visited the Williamsport Area Community College (WACC) and the Altoona campus of The Pennsylvania State University (APSU) to: (1) observe students in two-year technical programs in English and speech classes; (2) discuss strategies of CAI with instructors; and (3) lay the groundwork for a field trial of the completed spelling segments.

Students at WACC and APSU were asked by local staff members to participate in the field trial, with the understanding that participants would be paid a nominal sum when they completed the tasks involved.

Because of the reading involved in the CAI spelling program, it was important to have an indication of the students' reading ability. No standardized reading or English achievement scores were available for the WACC students; therefore, arrangements were made to administer to them the reading comprehension and English placement tests constructed by The Pennsylvania State University Office of Student Affairs Research. These tests constitute part of the test battery administered to students applying for admission to The Pennsylvania State University (PSU), and consequently, the scores obtained by the

APSU students on the tests were available from the Office of Student Affairs Research.

A 40-item questionnaire (Brown, 1966 and Wodtke, 1965) designed to elicit student attitude toward CAI was expanded to cover 44 items. This questionnaire was administered to all participants after they had completed the CAI spelling course (Appendix C, p. 121).

The Field Trial

A field trial was designed to obtain information about the general "takeability" of the spelling program segments, and to provide bases for editing and revising the program. The study was conducted at WACC and APSU from October 31, 1966, to December 9, 1966.

Twenty-five students at WACC and 16 students at APSU participated in the field trial. Because of equipment malfunctions and proctor errors, data from 12 Subjects (Ss) at WACC and 4 Ss at APSU were incomplete and are not included in this. All Ss were enrolled in two-year programs of study at their schools. The 25 participants were majoring in the following courses at their schools: 10 in technical subjects (e.g., electronics, drafting, construction, machine and electrical technology) and 15 in business courses (e.g., general business, accounting, business management, retailing, agricultural business). The numberof students enrolled in each area is shown in Table 4.1. The ages of the Ss ranged from 18 to 27 years; 14 Ss were men and 11 were women.

Preliminary Findings and Apparent Trends

The analysis of the data gathered from the study has not yet been completed. Nevertheless, several trends have emerged from the preliminary analyses, and it is clear that the information will be helpful in editing and revising the program.

The following preliminary findings are already evident: (1) The range of all scores for the APSU Ss was narrower than for the WACC Ss. (2) Gains were recorded by two-thirds of the APSU Ss; all but one of the WACC Ss made gains. More of the Ss at WACC made larger gain scores than the Ss at APSU. The mean gains were greater at WACC than at APSU. Men students generally made greater gains than women students except that sex differences were confounded with school as shown in Table 4.2. (3) As shown in Table 4.3, there appears to be a positive correlation between achievement gain scores and the number of course segments covered by the student. There is no apparent relationship between the number of equipment malfunctions encountered by the student and the gain. (4) Generally, the scores on the attitude questionnaire appear unrelated to the amount of gain revealed by the gain scores as shown in Table 4.4[1]. Women Ss had a higher mean score (positive) on the attitude questionnaire than men.

---

[1] A complete correlational analysis was unavailable for this report; however, the final analysis will be completed in the near future.

Table 4.1

Biographical Information on Ss in Field Trial of Remedial Spelling Course

	APSU	WACC
Men	3	11
Women	9	2
TOTAL	12	13
Course Majors:		
Business		
General Business		2
Accounting		1
Business Management		2
Retailing	9	
Agricultural Business	1	
Technical		
Electronics		3
Drafting	1	1
Construction		2
Machine		1
Electrical Technology	1	1
TOTAL	12	13

Table 4.2

Scores on 37-item Spelling Test for 25 Students in Field Trial

(Maximum possible score 50[1])

APSU					WACC				
Sex	Pre-test	Post-test	Gain Scores	Terminal Time	Sex	Pre-test	Post-test	Gain Scores	Terminal Time
W	26	34	8	5:00	W	20	43	23	8:23
M	32	39	7	5:48	M	29	47	18	5:35
M	26	33	7	5:42	M	22	34	12	10:09
W	45	48	3	2:25	M	28	37	9	6:41
W	47	50	3	2:53	M	25	34	9	8:20
M	35	38	3	7:01	M	21	28	7	7:34
W	46	48	2	2:25	W	31	37	6	5:18
W	35	37	2	6:45	M	38	43	5	3:05
W	45	45	0	1:56	M	33	38	5	4:16
W	42	42	0	2:26	M	34	38	4	5:58
W	43	41	-2	3:23	M	39	42	3	2:31
W	41	39	-2	3:24	M	40	41	1	3:06
-	-	-	-	-	M	39	39	0	2:32
Mean	38.58	41.08	2.58	4:50		30.69	38.53	7.84	5:38

---

[1] *N.B.* Maximum score of 50 on this 37-word diagnostic spelling test is possible because several words diagnose more than one type of error(see p. 63).

Table 4.3

Rank Ordering of Absolute Gains with Number of Course Segments and Equipment Malfunctions

APSU			WACC		
Gain Scores	Number of Segments Studied	Weighting of Equip. Malfunction (#30)*	Gain Scores	Number of Segments Studied	Weighting of Equip. Malfunction (#30)*
8	9	3	23	14	4
7	9	3	18	9	3
7	8	5	12	11	5
3	8	2	9	9	2
3	5	3	9	9	4
3	5	2	7	9	2
2	8	1	6	8	3
2	5	3	5	7	4
0	5	5	5	7	3
0	5	3	4	7	4
-2	6	3	3	6	3
-2	6	2	1	6	3
-	-	-	0	5	5

*Item 30 on Attitude Questionnaire reads:

While on Computer Assisted Instruction I encountered mechanical malfunctions.

(Weighting)	(1)	(2)	(3)	(4)	(5)
	:	:	:	:	:
	Very Often	Often	Occasionally	Seldom	Very Seldom

Table 4.4

Attitude Toward CAI by Gain and Sex

APSU			WACC		
Positive Attitude Scores	Gain Scores	Sex	Positive Attitude Scores	Gain Scores	Sex
180	3	W	168	23	W
177	2	W	166	18	M
170	7	M	165	12	M
169	0	W	163	9	M
165	0	W	161	4	M
163	-2	W	160	9	M
161	-2	W	160	6	W
157	3	W	160	0	M
154	7	M	159	3	M
152	2	W	157	2	M
144	8	W	151	7	M
140	3	M	147	5	M
-			124	1	M
Mean 161	2.58		Mean 157	7.61	

APSU:

Men $\overline{X}$ = 154.6
Women $\overline{X}$ = 163.1

WACC:

Men $\overline{X}$ = 155.7
Women $\overline{X}$ = 164.0

Discussion

It must be remembered that complete statistical analyses have not yet been completed on the data discussed in this report, and the findings reported above should be regarded as preliminary until all of the planned statistical analyses have been completed.

Table 4.5

Tabulated Responses for
Attitude Questionnaire Item

Item 44:

How long do you feel you could work efficiently in computer-assisted instruction at one sitting: (circle one)

	1/2 hour	1 hour	1-1/2 hours	2 hours	More than 2 hours
APSU	0	1	2	8	1
WACC	0	6	4	3	0
TOTAL	0	7	6	11	1

However, the preliminary examination of the data does suggest answers to some of the questions that this field trial was planned to explore.

1. The narrow range of scores for APSU Ss may be a consequence of two facts:

   (a) The APSU Ss were a sample from a population previously screened by meeting university admissions requirements.

   (b) Of the 16 APSU Ss, 13 were enrolled in the same course of study, thus reducing variability in spelling achievement to some extent.

2. The program, even without needed editing and revision, appears to be a way for students to learn spelling skills. As might be expected, the program was especially helpful to those Ss who were poor spellers as indicated by their low pretest performance. This is inferred from the comparison between those whose performances showed gains (i.e., 20 Ss) and those whose performances showed no gain (i.e., 3 Ss) or a loss (i.e., 2 Ss).

3. The greater gains shown by men as contrasted with women students is in keeping with usual expectations for enrollees in technical courses. These findings are of course confounded with the schools which the students were attending and further field trials will be undertaken with student samples from both sexes in both locations. The women had higher scores on the pretest; consequently, they had less opportunity to make gains, and considerably less need for a course of instruction in remedial spelling. Furthermore, the women in the field trial had higher mean scores on the PSU reading comprehension test ($\bar{X}$ = 12.5) and on the English placement test ($\bar{X}$ = 50.1) in contrast to men whose mean scores on the same two tests were 11.6, and 34.6, respectively.

4. Unless Ss experience a minimum of equipment malfunction when they are taking a CAI course, they tend to regard CAI as an interference in their learning, rather than as a help. Of the 40 Ss who originally enrolled to participate in this study, the data from 15 could not be included in the analysis because the Ss encountered extensive machine failure and proctor error. The mean attitude score of these excluded students was less positive ($\bar{X}$ = 151.8) than that of Ss whose data were retained ($\bar{X}$ = 159).

5. Confidence in the validity of the pretest has been increased by the positive relationship between the number of spelling course segments studied and the positive gain scores. Ss were routed into remedial course segments according to their performances on the pretest.

Implications

The implications made by the preliminary analysis of data from this field trial are promising. Depending on the completion of the data analysis, it appears that further research on the use of a CAI spelling program with poor spellers in two-year technical courses is indeed merited.

Efforts to eliminate malfunctions of equipment should be of primary concern to researchers. There is some evidence that this may involve the more careful and thorough training of terminal proctors assisting in a study, as well as the more rigorous and systematic testing and retesting of the equipment used, and of the computer program as it is executed at the terminal.

Since the program has demonstrated that remedial spelling courses can be taught by CAI, it would seem that a new field trial should be initiated with a revised and edited version of the course.

References

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Wodtke, K. H., Mitzel, H. E., and Brown, B. R. Some preliminary results on the reactions of students to computer-assisted instruction. Proceedings of the American Psychological Association, 1965.

CHAPTER V

RESEARCH REPORTS

Cueing and Feedback in Computer-Assisted Instruction

Keith A. Hall, Marilyn Adams, and John Tardibuono

It is not appropriate at this point of development to maintain that the CAI can or does provide more efficient methods of teaching. Rather it is more appropriate to scrutinize the particular characteristics of a given system for improvement of learning. Many of these characteristics or variables cannot be judged in terms of previous experimentation because they do not exist in other learning experiments or situations. Further, studies conducted in laboratory situations cannot be readily transferred to an educational environment. This study attempts to remove the psychological learning experiment from the artificial world of animal laboratories and nonsense syllables and to place it in educational context.

The CAI system at Penn State University has two *Coursewriter* functions (among others) for providing feedback to students regarding the correctness of their response. Each of the functions gives the author flexibility in selecting the type of feedback to provide to the student. At this point though, there is no information available to guide the author in making a choice. The two functions under investigation are keyword (kw) and partial answer zero (pa0). (See Chapter I for an interpretation of mnemonic codes.) The keyword function can be used to match a student's response against a stored correct response in a block consisting usually of a complete word or several complete words. A decision is made by the system on the basis of a complete word matching or not matching. The pa0 function causes the system to match a student's response against the stored correct response a single character at a time or in groups of characters at a time depending on the author's decision. In each case feedback can be given to the student based upon what was matched and what was not matched.

The simplest form of feedback with kw is for the system to type at the student terminal the complete response which he should have made. The simplest form of feedback with pa0 is for the system to match the response made by the student character by character against the stored correct response and type back at the student terminal the characters which matched correctly, dashes for lowercase characters which _did not_ match, and underscores for uppercase characters which _did not_ match.

A typical student-system interaction using kw with immediate feedback of the correct response might look like this. The system types "Colorado" and the student is to type the capital of that state. If the student types "Boulder," the system will respond "Denver." Using the pa0 function the interaction would differ. If the student typed "Boulder" the system would respond "De---r," In this case the system searched the student's response "Boulder" and found three characters which are part of the correct response -- d, e, and r. The system rearranged these into the proper order and typed them for the student in their proper location.

Programs have been written for investigating the effectiveness of these two kinds of feedback. A paired-associate learning task is employed using fifty pairs which the student must learn. The fifty state names of the United States are presented as the stimulus items and the student will learn to respond with the names of the capitals. The items are presented one at a time to the student at the terminal typewriter in random order. If the student responds correctly on his first trial to that stimulus, it drops from the program. The program recycles until each student has responded correctly on his first trial to each of the stimulus items. After he had "acquired" each of the fifty pairs,he again goes through the list as a posttest. Each student takes a retention test two weeks after the initial treatment.

Each of the experimental programs contains the following features:

1. A list of warm-up items consisting of five countries presented as stimuli and their capitals as response items.
2. A typing test which reports a student's time and accuracy in typing an alphabetic sentence.
3. A progress report to the student after each trial through the list of states consisting of
    (a) total number of responses
    (b) total number of stimuli presented
    (c) total number of items acquired

   (d) total response latency

   (e) current clock reading

4. An automatic five-minute break approximately half way through the task.
5. An automatic connection to a system administered student opinion survey regarding CAI.

A preliminary investigation was conducted during the Fall Term 1966, with ten subjects on each program. The results, though not conclusive, have encouraged the authors to continue collecting data with a large sample of students. The two experimental treatments are now being administered to students from the Williamsport Area Community College.

Relative Effectiveness of Three Modes of Presentation Through Computer-Assisted Instruction

Donald W. Johnson

This study was undertaken to provide some answer to the computer-student interface problem. Often when writing material for CAI, an author is confronted with the problem of deciding which mode of presentation he should use. His choices currently are among the typewriter output, audio tape messages, 2 x 2-inch photographic slides, or in some cases static displays. (Static displays are usually in the form of papers, booklets, or three-dimensional models.) In some instances these choices are determined by the subject matter being presented, (i.e., when presenting stimulus material to test spelling ability, an audio message is the logical choice). However, the presentation mode in many instances is not so well defined.

The purpose of the study is to determine the relative effects of three modes of presentation, audio tape, typewriter output, and static displays on total time required for subjects to complete the course and on competence as determined by a posttest score.

Method

Course material chosen for the study was a physics sequence on "Working With Units." It is a basic physics series designed for vocational-technical students who have finished high school and have a limited background in mathematics and physics.

The sequence originally contained material presented through typeout with nine slides supplementing the printed verbal material. Questions were included throughout the sequence to provide for student interaction. Written verbal typeout contained the basic instruction and could be considered the core of the short course.

This core instructional material was transcribed word-for-word on audio-tape to provide the audio mode and was placed in a booklet to provide the static display mode. The original material was labeled the type mode.

All subjects in all modes viewed the same slides and answered the same questions; only the instructional material was altered through a change of presentation mode. A fourth group, identified as the control group, took the final examination only and received no instruction. Subjects were placed in groups by random assignment.

The subjects were approximately ninety juniors and seniors in the College of Education enrolled in an introductory instructional media course. They did not have a mathematics or physics background.

Type Mode. In the type mode, the subject signed on the course, the computer typed out instructions then typed a question, the subject typed the answer to the question, a slide was shown, illustrative material about the slide was typed, etc., until the lesson was completed. The subject was immediately tested on his knowledge at the terminal by a computer administered test. Total instructional time and test score was recorded.

Audio Mode. Subjects who received instruction through the audio mode heard the same material that the subjects in the previous mode read from the typeout. Subjects could repeat each message as often as desired but could not read or by-pass any material. When finished, they took the same computer administered test.

Display Mode. Subjects in the display mode had a booklet in their hands containing all of the messages heard or read by the above groups. The typeout instructed them to refer to and read the proper page of instruction. Slides were shown in the proper sequence by the computer and questions asked at the proper time. Answers to the questions were typed by the subject. The same computer administered test was taken by this group.

Control Group. The control group only took the test at the computer terminal.

We have just completed the instruction of the subjects and the collection of the data; it has not yet been analyzed.

Application of a Modified Gagné Type Model to Computer-Assisted Aptitude Testing and Instructional Branching

Harold Sands

Although twentieth century concern with individual differences has come to the fore in such modern developments as mental testing, counseling and guidance, multi-tract curricula, ability grouping, ungraded classrooms, perhaps one of the most direct attacks on the problem vis-a-vis instruction has come from the recent arrival on the educational scene of computer-assisted instruction. The computer has been heralded for extending the decision-making capabilities of educators far beyond potentials which have existed in the past; however, it is doubtful if we have even begun to utilize these capabilities. Perhaps the most glaring examples of this are in methods used for aptitude testing and branching. It is an old adage to ". . . start with a student where he is . . . ." In instructional practice, use of the computer has brought about few changes which really extend the advantages accrued beyond traditional aptitude and achievement testing. In instructional branching, where one might expect even greater changes, progress has not been much better.

Although such variables as latency and error rate are currently being explored, the best current method for branching is based on programmers' intuitive judgment. If a student makes an error in responding, he is branched to other stimulus material because in the judgment of the programmer, all students who have made that error need that particular change in their instruction. Such approaches, while they are certainly an attempt in the direction of individualizing instruction, have also been accomplished through scrambled-book programs, and can hardly be said to be making full use of the decision-making capability which educators purportedly will soon have in computer-assisted instruction.

The recently initiated research described in this summary is an attempt to further enhance the individualizing capability of computer-assisted instruction by extending the testing and branching capabilities traditionally available.

Theoretical Framework

Gagné (1962) maintains that the acquisition of knowledge proceeds in a hierarchal fashion from lower level learning sets to higher level sets until mastery of the criterion is achieved. Learning sets are conceived as specific behaviors which mediate positive transfer to the next superordinate set in the hierarchy. Theoretically, one cannot achieve mastery of the next higher learning set unless he has mastered all sets subordinate to it. Such hierarchy might be organized into blocks of learning sets as shown in Fig. 5.1.

Theoretically, for example, a student cannot master Level I unless he has mastery of Sets A, B, and C of Level II and of their subsets. In several studies, Gagné and his associates have been able to demonstrate the existence of such hierarchies in the teaching of mathematics. In one study (Gagné, Mayor, Garstens and

Paradise, 1962), a hierachy for the addition of integers was identified. After the administration of a program, the acquisition of learning sets at successively higher stages of the hierarchy was found to be dependent upon prior mastery of subordinate learning sets. Predictions of instances in accord with predictions ranged from 97 to 100 per cent. Confirmatory results have been obtained in a study by Gagne and Paradise (1961) which was concerned with the class of tasks of solving linear algebraic equations, and by Gagne and Basler (1962) in which the task was that of specifying sets, intersections of sets, and separations of sets, using points, lines and curves.

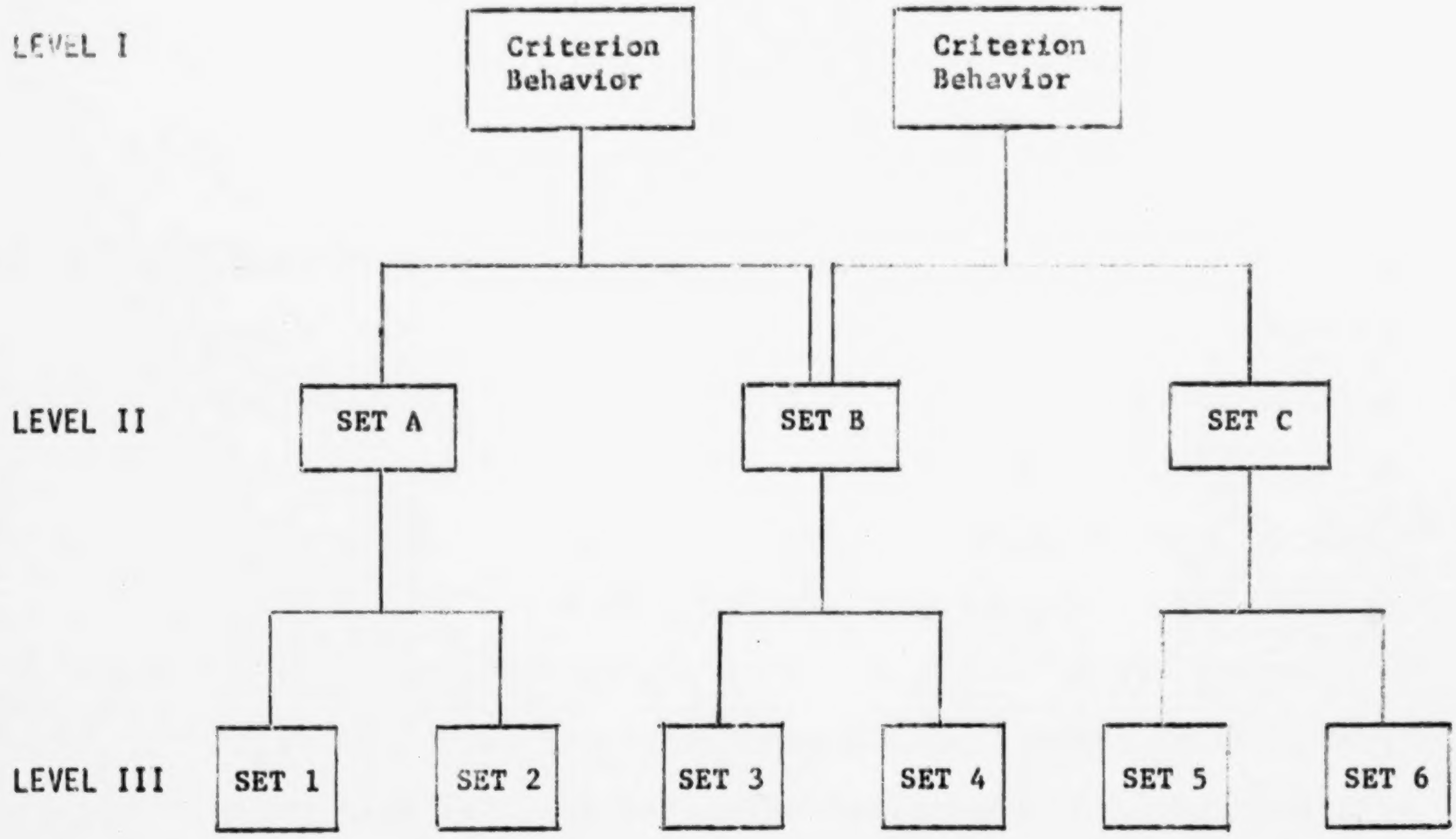
LEVEL I
Criterion Behavior
Criterion Behavior
LEVEL II
SET A
SET B
SET C
LEVEL III
SET 1
SET 2
SET 3
SET 4
SET 5
SET 6

Fig. 5.1 Hypothetical model of knowledge hierarchy in which lower level learning sets mediate positive transfer to higher level sets.

Implications of Gagné's Idea for Computer-Assisted Aptitude Testing

If this construct is correct, then it seems to be particularly relevant to computer-assisted testing. If learning is really hierarchial, and if tests are developed to measure performance of each set in the hierarchy, then tests could be administered in a manner similar to the Stanford-Binet, in which the highest set in the hierarcy for which the individual had mastery was identified. If the test and hierarchy are valid, it would not be necessary to test lower or higher sets for which the individual had mastery, since presumably, he must have mastery of all subordinate sets and cannot have mastery of superordinate sets. It should be noted that such a test requires the availability of test items for possibly hundreds of learning sets, an interpretation of student responses, and a decision-making capability by the tester to either test further or to prescribe instruction. Such a test must be administered individually; therefore, it requires a live tester or an adequate substitute, perhaps a computer. The latter is considerably more practical and is probably more accurate. A student who is to learn mathematics could be seated at a terminal and tested in order to identify his highest level of learning set achievement. Instructional sequences or "tracts" from which he could derive benefit could be made available by a teacher; or if decision-making criteria had been programmed into the system, instructional assignments could be made by the program of the computer.

Implications of Gagné's Idea for Branching

The testing functions discussed thus far described a system in which a student is tested and differentially placed into a teaching sequence which represents his highest level of learning set achievement. Once placed into a sequence according to past achievement, individual differences in the learning of new material must also be accounted for. Whereas pre-testing may allow for individual differences in past achievement, branching allows for individual differences in learning abilities. Branching can, for convenience, be thought of as consisting of two functions. First, a student is tested and his response is evaluated. Secondly, the student is presented with stimulus material which, on the basis of the test response, is optimal for him at that time. Although other criteria are involved in maximizing the advantage of such a student-tutor relationship, one of the requirements is that there be a unit of identifiable behavior to be tested and to which the student is to be branched. In the jargon of programmed instruction these have sometimes been referred to as "steps." In branching, it seems that learning sets could serve as the logical units of behavior for testing as a student progresses through a program and for branching intended to allow for individual differences in learning abilities. If a student cannot master a particular learning set, there would, theoretically be little advantage in advancing him to the next higher learning set. In fact, subordinate learning sets might be tested until there was some assurance that the student has mastery of all requisite sets.

The Current Research

The purpose of this research is to investigate Gagné's notion that higher mental processes are structured by learning sets which are hierarchically ordered, and the full implications of this idea for testing as well as branching in a computer-assisted instructional system. Actually, several modifications have been made in the type of hierarchy identified and in methods for arriving at it. The study has been divided into three phases:

1. The development of methods for analyzing subject matter and identifying hierarchies of learning sets.
2. The development of methods for testing and identifying a student's level in a hierarchy of learning sets.
3. The development of computer-assisted instructional materials which incorporate the application of theoretical findings to a more highly developed system of individualized instruction through branching and other teaching strategies based on the methods of diagnostic testing developed and using sets in hierarchies as the primary unit of learned behavior.

The first phase which is reported here is concerned with the identification of a subject matter hierarchy. A hierarchy has been identified and is currently in the process of being validated. The task selected was a simple one, to convert a number in one base to its equivalent in another base. The remainder of this paper is devoted to a description of how the hierarchy was developed and to a discussion of how such a hierarchy can be validated.

The Hierarchy

The procedure for analyzing the task (converting a number from one base to its equivalent in another base) and identifying a hypothesized hierarchy was slightly modified from that of Gagné's; however, the hierarchy which results is somewhat different, having two rather than one dimension, and consisting of conceptual levels, each of which contains the total components of criterion behavior, but at different conceptual levels. To arrive at this type of hierarchy, the questions were asked of the final criterion, "What does a person do when he performs this task?" "Can what he does be described by dividing the final task into two subsets?" If not two, then three and so on. These latter sub-sets become Level II learning sets, and each of these was in turn divided into Level III sets, with the procedure continuing until five levels were identified. In all, the model consists of approximately 30 learning sets. The first three levels of this hierarchy are shown in Figure 5.2, and will be used as a more specific example of how the hierarchy was formed. Starting with Level I, the criterion performance, it was decided that what a person does in making the conversion could be described as consisting of two subordinate sets. These are the two sets shown as Level II. Had the final Level I performance not been divisible by two, then successive divisions of three, four and so on would have been tried until the least number of sets were arrived at which were greater than one, but which completely described the criterion performance. Each of the two sets at Level II were subdivided following the same procedure.

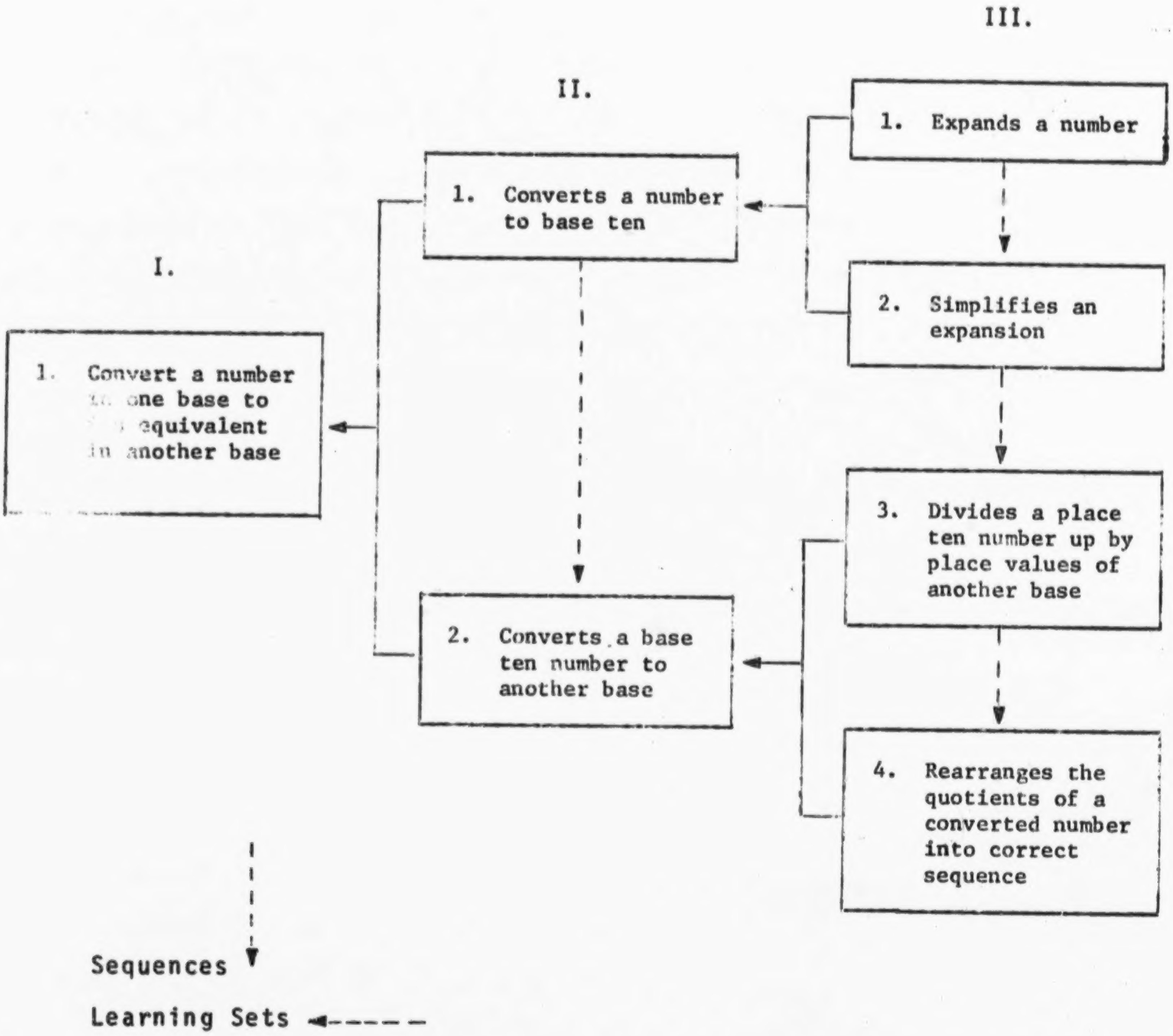
III.
II.
1. Expands a number
1. Converts a number to base ten
I.
2. Simplifies an expansion
1. Convert a number in one base to its equivalent in another base
3. Divides a place ten number up by place values of another base
2. Converts a base ten number to another base
4. Rearranges the quotients of a converted number into correct sequence
Sequences
Learning Sets

Fig. 5.2. Partial hierarchy of learning sets for the criterion performance of converting a number from one base to its equivalent in another base.

Learning sets III-1 and III-2, according to the theory of hierarchal learning, mediate positive transfer to set II-1. Set II-1 and II-2 mediate transfer to I-1. If any of the subordinate learning sets are not mastered, then theoretically, learning of the higher level set cannot occur. For example, if an individual has not mastered levels III-3 and III-4, he should not be able to learn set II-2.

A further examination of Figure 5.2 will reveal that as one proceeds from the top set at each level downward, the sequence of learning sets is the same sequence in which the criterion behavior must be performed. This is another modification of the way in which Gagné organizes his hierarchies; however, since integration of subordinate sets plays such an important role in his construct, it was felt that by organizing the sets sequentially, the meaning of "integration" or the "putting together" of subordinate sets was made clearer. This assumes, of course, that integration consists primarily of selecting or recalling relevant learning sets and of performing them in a sequence appropriate to the given task. In cases where the sequence is arbitrary, the learning sets in question are joined by boxes which are contiguous to each other, but none occurred in the first three levels.

For purposes of this study, only the first four levels which consist of 15 learning sets, are being used.

Validation of the Hierarchy

The hierarchy is in the process of being validated, and data should be available for the next reporting period. Gagné's premise has implications for validity. Sets in the hierarchy provide fairly specific behaviors against which test items can be compared. Secondly, if the test is accurately measuring the highest level of achievement in the hierarchy, then it should be an easy matter to demonstrate that individuals who lack mastery of a lower set, lack mastery of higher sets. Finally, the validity of such tests might be demonstrable on the basis of showing a relationship between the measured level of learning set attainment and conventional achievement scores taken at the end of a training period.

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An Instrument for the Measurement of Expressed Attitude Toward Computer Assisted Instruction[1]

Bobby R. Brown

It is generally agreed that student attitude and motivation are important variables in the traditional learning situation. In the lecture method the student, it is often said, should have a positive attitude toward the teacher and the subject matter content as well, if optimal learning is to take place (Bugelski, 1964). However, in programmed instruction, and especially automated instruction, such as computer-assisted instruction (CAI), there will be less direct contact between teacher and student. It seems important therefore to assess the effects on learning of student attitude toward this kind of instruction. The results of some previous investigations seem to indicate that student attitude toward automated instruction may not be of much consequence relative to the amount learned (Eigen and Feldhusen, 1964; Wodtke, Mitzel, and Brown, 1965; Wodtke, 1965). It may well be that the effects of student attitude only show up over an extended period of time and that these studies were too short-termed to give a true indication of the effects of student attitude. One study which did report significant changes in attitude was interestingly enough a study of eight months' duration (Campbell and Chapman, 1965).

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[1] Developed while the author was on an IBM fellowship at The Pennsylvania State University, with helpful advice from Professor Robert Lathrop.

The studies cited above, however, have one thing in common: they all measured attitude with experimenter-constructed tests of either unknown or unreported reliability. If anything definitive is to be said about student attitude and programmed instruction, some effort must be put into developing better measuring instruments. This is a report of one effort to develop a more satisfactory measure of student attitude toward CAI, and a description of the instrument in its present state of development.

General Description and Statement of Intended Application of the Instrument

The attitude instrument consists of forty items, each of which is a statement that could be made about CAI or about oneself in relation to CAI, and each of which is to be responded to by marking one of five choices on a Likert-type scale. The response device was designed to be used for research purposes only and was planned specifically to be used in research in the CAI Laboratory at Penn State.

The inventory was designed and preliminary data have been analyzed with the plan to use the method of summated ratings to obtain one score of student attitude (Edwards, 1957). The user should refrain from making statements on the basis of responses to individual items in the test, and be aware that the reliability of individual items will at best be quite low. Also, because of the difficulty encountered in interpreting a summated rating score with reference to a neutral point or neutral score, it becomes difficult to assign individuals to favorable or unfavorable categories. This difficulty is not encountered, however, if one's research interest calls for measuring change in attitude or for correlation measures.

Sources of the Items

The items in the inventory (see Appendix C, p.121) came from three sources:

1. Four items were taken from a student reaction inventory previously developed by Dr. Wodtke at The Pennsylvania State University CAI Laboratory. These four items were reworded to make them compatible with the five-point Likert-scale used in the present instrument.
2. Sixteen items were based on comments previously written by students who had been engaged in CAI.
3. Twenty items were based on the author's observation of students' reactions while they were engaged in CAI and on students' comments to the author during informal conversation after they had been engaged in CAI.

Wording of the Items

In order to add some protection against haphazard marking of the items and to minimize the possible effects of response set, some of the items were stated negatively (i.e., were statements of negative attitude toward CAI), and some were stated positively. Two statements were incomplete until the student marked his responses, and his responses determined whether the statements were negative or positive. One of the incomplete or neutral statements was: "Concerning the course material I took by CAI, my feeling toward the material before I came to CAI was: Very Favorable, Favorable, Indifferent, Unfavorable, Very Unfavorable."

Unanimous agreement among six judges was obtained on the classification of items as negative or positive. The breakdown of the items as negative, positive, or neutral is given in Table 5.1.

Table 5.1

Listing, by Item Number, of Negative, Positive, and Neutral Items

Type Statement	Item Number	Total
Negative	1, 3, 4, 6, 8, 10, 12, 13, 16, 17, 19, 22, 23, 24, 26, 29, 30, 32, 34, 35, 36, 40	=22
Positive	2, 5, 7, 8, 11, 14, 15, 18, 20, 21, 25, 31, 33, 37, 38, 39	=16
Neutral or Incomplete	27, 28	= 2

In order to make the students' choice of response more compatible with the wording of the items, four different labelings of the scale were used in the test. These are as follows:

> Strongly disagree, Disagree, Uncertain, Agree, Strongly agree
>
> All the time, Most of the time, Some of the time, Only occasionally, Never
>
> Quite often, Often, Occasionally, Seldom, Very seldom
>
> Very favorable, Favorable, Indifferent, Unfavorable, Very unfavorable.

Subjects

The subjects used for the pilot administration reported here were taken from an available group of students who had received some instruction by CAI sometime during the three previous terms at Penn State. Approximately twenty-five of the students were from the local high school, thirty-one from an introductory educational psychology class, and twelve Penn State students from an audiology class who were receiving instruction on CAI as part of a course they were taking for credit.

The students received their instruction in one of four courses and two students received instruction on two courses. It will be observed that the available group differed on at least the following dimensions: age, amount of time on CAI, educational level, whether or not they were taking the course for credit, and length of the interval since they were on CAI. From this group sixty-eight students were available. The breakdown of student by course is given in Table 5.2. Two students had both modern mathematics and physics but are counted only in physics.

Administration

The CAI attitude inventory was mailed to each of the students along with a letter and a self-addressed, stamped envelope. Thirty-four forms were returned. The number and percentage of returns is given by class in Table 5.2. Six forms were returned too late to be included in this analysis, and eight forms were returned unopened because the students had moved. Adjustment for these 14 untallied forms yields a total return of 67 per cent.

Table 5.2

Description of Study Group as to Courses Taken,
Number and Percentage of Forms Sent Out,
and Number and Percentage of Forms Returned

Course	No. sent out	% of total sent out	No. returned	% of total returned	% returned by class
Acphys.	23	33.8	17	50	73.9
Audiol.	12	17.6	1	2.9	8.3
Mod Math 1	18	26.5	11	32.4	61.1
RSMM	15	22.2	5	14.7	33.3
Totals	68	100.0%	34	100.0	50.0%

Analysis of Data from Pilot Administration

Reliability. The 34 tests returned were scored and inter-item correlations were obtained. A principle-components factor analysis and varimax rotation of the factor loading were performed in order to determine whether there appeared to be strata of items within the instrument. Six factors were extracted in the factor analysis and their Eigen values are 12.4, 2.8, 2.7, 2.3, 2.2, and 2.1. This indicates that the first factor is accounting for approximately 31 percent of the total variance in the form and the remaining factors something less than

7 per cent of the variance for each factor. The internal consistency reliability of items was computed. This coefficient was computed by the analysis of variance method. The coefficient obtained by this method is identical to the coefficient obtained by Kuder-Richardson Formula 20 (Dick, 1965; Rabinowitz and Eikeland, 1964). This coefficient was .885. The analysis of variance summary table for this estimate of reliability is presented in Table 5.3.

Table 5.3

Analysis of Variance Summary Table of Reliability

Source	D.F.	Sum of Squares	Mean Squares
Subjects	33.	238.36	7.2231
Items	39.	1072.58	
Residual	1287.	1067.87	0.8297

$R = 1 - 0.830/ \quad 7.223 \quad = \quad 0.885$

$$R = 1-\frac{MS_e}{MS_s}$$

Mean intraitem correlation = 0.162

Non-stratified reliability = 0.885

In addition, internal consistency coefficients were computed using the factor loadings from the factor analysis to construct strata of items. As set forth by Rabinowitz and Eikeland (1964), this method will give a better estimate of the reliability of a test if there are clusters or strata of items in the test. The coefficients given by this analysis are .859 if strata are considered random and .890 if strata are considered fixed. The analysis of variance summary table for these estimates of reliability are presented in Table 5.4.

Table 5.4

Analysis of Variance Summary Table
of Reliability by Strata

Source	D.F.	Sum of Squares	Mean Squares
Subjects	33.	238.36	7.2231
Strata	6.	170.75	
It/Strat	33.	901.83	
S X S	198.	202.17	1.0211
Residual	1089.	865.70	0.7950
Total	1359.		

Reliability Estimates

R = 1 - (1.021/ 7.223) = 0.859 Strata Random

R = 1 - (0.795/ 7.223) = 0.890 Strata Fixed

It should be observed that very little change in the coefficients resulted when the stratified analysis was performed. This result considered in connection with obtained Eigen values of the factors on which the strata were based suggests two possibilities: (1) the inventory may consist of one group of relatively homogeneous items, or (2) the fact that there was a considerable interval between the students' experience with CAI and the administration of the test may have resulted in their expressing a generalized attitude toward CAI which would prevent any meaningful factors showing up in the analysis. Regardless of which of these possibilities has occurred, the factors of items become rather meaningless and no attempt will be made to deal further with the factors until additional data are obtained.

In addition to the usual caution to be exercised in interpreting reliability coefficients, the nature of the available group and the method of administration must be kept in mind. It is quite possible that attitude toward CAI was a factor related to whether or not students returned the form. The reliability reported here might not have held up if data for all students had been available.

Validity. There is no statistical evidence of the validity of this attitude inventory at the present time. Evidence of content validity is presented in this section.

The device appears to be measuring student attitude toward CAI. The items consist of possible statements of attitude toward aspects of CAI or comparative statements about CAI and traditional instruction.

The strongest argument presently available as to the validity of this form is that the items can be considered to have a quasi-sampling or logical validity. The items were constructed from actual observed or written expressions of students' stated attitudes about CAI. Because it was felt that an expression of attitude toward CAI would involve little emotional or ego involvement, the items were written to get at "expressed attitude" and no effort was made to get an indirect measure of attitude. Inasmuch as the inventory was designed to measure expressed attitude and because the items were constructed from instances of actually expressed attitudes, it is felt that evidence of more substance than mere face validity has been presented for the scale.

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APPENDIX A

A.1 Students within Sequence Numbers, All Separate
A.2 Sequence Numbers within Students, All Separate
A.3 Students Separate, Sequence Numbers Pooled
A.4 Sequence Numbers Separate, Students Pooled
A.5 Statistical Summary Listing

Appendix A.1

Students Within Sequence Numbers, All Separate

COURSE NAME - Sigfig100 AUTHOR - Tracy Logan 9/20/66 - 11/12/66

Student No.	Sequence No.	Attempts	Mean Latency	Sd of Latency
586	AA-0010-018	2	79.53	71.057
589	AA-0010-018	2	86.30	26.121
590	AA-0010-018	2	83.95	79.309
595	AA-0010-018	1	65.03	0.000
615	AA-0010-018	2	49.28	17.748
618	AA-0010-018	1	13.33	0.000
628	AA-0010-018	2	38.43	31.190
633	AA-0010-018	1	150.00	0.000
634	AA-0010-018	2	65.24	19.184
637	AA-0010-018	2	47.72	48.317
641	AA-0010-018	1	76.20	0.000
647	AA-0010-018	3	75.32	48.671
662	AA-0010-018	1	137.75	0.000
618	AA-0010-018	1	88.86	0.000
801	AA-0010-018	2	89.16	57.177
586	AA-0020-020	1	20.23	0.000
589	AA-0020-020	3	40.95	12.604
590	AA-0020-020	3	46.88	14.043
595	AA-0020-020	1	28.70	0.000
615	AA-0020-020	1	24.10	0.000
618	AA-0060-020	2	25.98	1.803
628	AA-0020-020	3	26.19	15.128
633	AA-0020-020	3	41.18	17.450
634	AA-0020-020	4	44.24	15.942
637	AA-0020-020	1	79.27	0.000
641	AA-0020-020	1	51.90	0.000
647	AA-0020-020	1	89.60	0.000
662	AA-0020-020	1	26.87	0.000
801	AA-0020-020	2	27.97	11.646
586	AA-0040-020	1	63.72	0.000
589	AA-0040-020	1	96.85	0.000
590	AA-0040-020	1	75.58	0.000
595	AA-0040-020	1	71.14	0.000
615	AA-0040-020	1	50.16	0.000
618	AA-0040-020	1	21.24	0.000
628	AA-0040-020	1	69.68	0.000
633	AA-0040-020	1	108.34	0.000
634	AA-0040-020	1	14.15	0.000
637	AA-0040-020	1	159.33	0.000
641	AA-0040-020	1	133.68	0.000
647	AA-0040-020	1	18.34	0.000
662	AA-0040-020	1	21.17	0.000
801	AA-0040-020	1	38.38	0.000
586	AA-0050-030	1	118.38	0.000
589	AA-0050-030	1	46.82	0.000

Appendix A.2

Sequence Numbers Within Students, All Separate

COURSE NAME - Sigfig100 AUTHOR - Tracy Logan 9/20/66 - 11/12/66

Student No.	Sequence No.	Attempts	Mean Latency	Sd of Latency
586	AA-0010-018	2	79.53	71.057
586	AA-0020-020	1	20.23	0.000
586	AA-0040-020	1	63.72	0.000
586	AA-0050-030	1	118.38	0.000
586	AA-0060-020	1	80.80	0.000
586	AA-0080-010	1	16.95	0.000
586	AA-0090-020	1	24.73	0.000
586	AA-0100-020	1	16.90	0.000
586	AA-0110-020	1	35.42	0.000
586	AA-0120-020	1	11.35	0.000
586	AA-0130-020	1	14.92	0.000
586	AA-0140-020	1	71.99	0.000
586	AA-0150-020	1	18.68	0.000
586	AA-0160-020	2	35.36	2.326
586	AA-0160-229	1	16.13	0.000
586	AA-0180-010	1	220.28	0.000
586	AA-0180-030	1	20.75	0.000
586	AA-0200-020	1	39.65	0.000
586	AA-0210-020	1	13.13	0.000
586	AA-0230-010	2	14.34	0.375
586	AA-0240-020	1	26.62	0.000
586	AA-0250-090	2	19.54	10.062
586	AA-0300-020	1	16.89	0.000
586	AA-0310-020	1	12.40	0.000
586	AA-0330-040	1	28.64	0.000
586	AA-0340-020	1	11.87	0.000
586	AA-0350-020	1	8.29	0.000
586	AA-0360-020	1	18.60	0.000
586	AA-0410-100	1	5.30	0.000
586	AA-0420-020	1	20.21	0.000
586	AA-0430-040	1	25.46	0.000
586	AA-0440-020	1	13.92	0.000
586	AA-0450-010	1	29.27	0.000
586	AA-0460-020	1	11.60	0.000
586	AA-0470-020	2	37.60	12.127
586	AA-0470-030	1	40.82	0.000
586	AA-0510-020	1	29.06	0.000
586	AA-0530-020	1	7.80	0.000
586	AA-0530-100	1	88.85	0.000
586	AA-0531-200	1	9.88	0.000
586	AA-0531-250	1	11.55	0.000
586	AA-0531-340	1	56.72	0.000
586	AA-0531-370	1	3.40	0.000
586	AA-0550-018	2	32.16	10.479
586	AA-0560-020	1	66.12	0.000
586	AA-0610-010	2	59.62	19.375
586	AA-0610-019	1	21.28	0.000
589	AA-0010-018	2	86.30	26.121
589	AA-0020-020	3	40.95	12.604
589	AA-0040-020	1	96.85	0.000
589	AA-0050-030	1	46.82	0.000
589	AA-0060-020	1	19.88	0.000
589	AA-0080-010	1	24.38	0.000

Appendix A.3

Students Separate, Sequence Numbers Pooled

COURSE NAME - Sigfig100   AUTHOR - Tracy Logan   9/20/66 - 11/12/66

Student No.	Attempts	Mean Latency	Sd of Latency	Frequency
586	54	35.64	5.110	52
589	67	31.35	3.765	65
590	58	37.61	5.467	56
595	49	28.79	5.125	48
609	13	21.08	3.985	12
615	45	21.93	2.645	43
618	60	23.42	3.768	58
628	47	37.59	7.767	45
633	41	60.04	8.741	40
634	56	37.82	4.797	54
637	69	60.55	11.296	67
641	22	42.76	7.753	21
647	56	46.22	8.350	53
660	32	29.19	3.520	31
662	63	27.82	2.903	62

Appendix A.4

Sequence Numbers Separate, Students Pooled

COURSE NAME - Sigfig100 AUTHOR - Tracy Logan 9/20/66 - 11/12/66

Sequence No.	Attempts	Mean Latency	Sd of Latency	Frequency
AA-0010-018	25	73.45	9.213	24
AA-0020-020	9	37.39	5.967	9
AA-0060-020	1	24.70	0.000	1
AA-0020-020	17	41.76	6.225	17
AA-0040-020	14	67.27	12.436	14
AA-0050-030	13	88.31	15.945	13
AA-0060-020	5	31.02	14.193	5
AA-0080-010	23	27.29	3.456	23
AA-0090-020	14	26.06	4.563	14
AA-0060-020	8	47.27	7.598	8
AA-0100-020	14	27.19	9.157	14
AA-0110-020	16	74.85	44.695	16
AA-0120-020	20	18.03	2.624	20
AA-0130-020	14	12.52	1.368	14
AA-0140-020	14	56.34	9.364	14
AA-0150-020	14	50.80	23.753	14
AA-0160-020	18	45.18	6.908	17
AA-0160-229	14	26.67	5.751	14
AA-0180-010	14	157.76	26.482	14
AA-0180-030	21	19.99	3.133	21
AA-0200-020	14	46.17	5.880	14
AA-0210-020	13	17.24	3.469	13
AA-0460-020	1	18.02	0.000	1
AA-0410-280	1	114.81	0.000	1
AA-0210-020	2	11.91	0.297	2
AA-0230-010	21	29.24	4.397	20
AA-0240-020	26	34.66	9.533	26

Appendix A.5

Statistical Summary Listing

T	Course	S	Seq. No.	Latency	Date	R1	X1	X2	Un	2	Clock
1	Sigfig100	S0586 82.62 CM2	AA-0010-018	129.77	9/29/66	10	.	.	0	*	170811.56
2	Sigfig100	S0586 82.6251 CM2	AA-0010-018	29.28	9/29/66	12	.	.		K	170906.17
1	Sigfig100	S0589 82.5 CM2	AA-0010-018	104.77	9/28/66		.	.	0	*	190836.59
2	Sigfig100	S0589 82.6251 CM2	AA-0010-018	67.83	9/28/66	4	.	.		*	191009.41
1	Sigfig100	S0590 78.345	AA-0010-018	140.03	9/28/66		.	.	0	*	180456.22
2	Sigfig100	S0590 82.6251	AA-0010-018	27.87	9/28/66		.	.		*	180549.39
1	Sigfig100	S0595 82.6251	AA-0010-018	65.03	10/04/66	8	.	.	0	K	202115.29
1	Sigfig100	S0615 82.7151 CM2	AA-0010-018	61.83	10/06/66	12	.	.	0	*	192306.35
2	Sigfig100	S0615 82.6251	AA-0010-018	36.73	10/06/66	1	.	.		*	192408.16
1	Sigfig100	S0618 82.911 CM3	AA-0010-018	88.86	10/03/66	10	.	.	0	*	203103.22
2	Sigfig100	S0618 82.6251	AA-0010-018	13.33	10/03/66	1	.	.		*	203141.55
1	Sigfig100	S0628 8263 CM	AA-0010-018	60.48	10/17/66	7	.	.	0	K	164127.38
2	Sigfig100	S0628 82.651	AA-0010-018	16.37	10/17/66	2	.	.		K	164208.02
1	Sigfig100	S0633 82.6251 CM2	AA-0010-018	150.00	10/05/66		.	.	0	*	201826.49
1	Sigfig100	S0634 82.8251 CM	AA-0010-018	78.80	10/05/66		.	.	0	*	190442.19

(continued on next page)

T	Course	S	Seq. No.	Latency	Date	R1	X1	X2	Un	2	Clock
2	Sigfig100	S0634 82.6251 CN M	AA-0010-018	51.67	10/05/66	13	.	.		K	190558.38
1	Sigfig100	S0637 92.6251 CM	AA-0010-018	81.88	10/10/66	4	.	.	0	*	163906.16
2	Sigfig100	S0637 82.6251 CM	AA-0010-018	13.55	10/10/66	4	.	.		*	163944.13
1	Sigfig100	S0641 82.6251 CM2	AA-0010-018	76.20	10/19/66	13	.	.	0	K	172010.34
1	Sigfig100	S0647 82.6258 CM	AA-0010-018	154.19	10/12/66	11	.	.	0	*	210442.21
2	Sigfig100	S0647 82.6258 1	AA-0010-018	27.40	10/12/66		.	.		*	210535.15
3	Sigfig100	S0647 82.6251 CM	AA-0010-018	44.36	10/12/66	11	.	.		K	210636.13
1	Sigfig100	S0662 82.6251 CM2	AA-0010-018	137.75	10/11/66	2	.	.	0	K	183618.32
1	Sigfig100	S0801 82.5251 CM2	AA-0010-018	129.59	10/20/66	2	.	.	0	C	195605.18
2	Sigfig100	S0801 82.625155	AA-0010-018	48.73	10/20/66	9	.	.		*	195717.22
1	Sigfig100	S0586 1/10 CM	AA-0020-020	20.23	9/29/66	8	.	.	0	C	171034.52
1	Sigfig100	S0589 Meters	AA-0020-020	61.45	9/28/66	1	.	.	0	*	191221.15
2	Sigfig100	S0589 CM	AA-0020-020	32.33	9/28/66	4	.	.		*	191326.50
3	Sigfig100	S0589 1/10 CM	AA-0020-020	29.08	9/28/66	2	.	.		K	191422.08

New, faster teaching methods supplement, not supplant, the teacher

Computer-Assisted Instruction for Technical Education

By David A. Gilman

Computer-Assisted Instruction Laboratory, Pennsylvania State University, University Park

Reprinted from November 1966 SCHOOL SHOP, Ann Arbor, Michigan

WITH PERMISSION

VOCATIONAL EDUCATION faces many problems, some of which are due to the changing character of our society. In certain areas of technology, the rapidity of technical and scientific advances has become so great that it is literally impossible to create curriculums for vocational-technical education that are *not obsolete* by the time they are taught in the schools. The extensive training required for employment in many technical occupations is imposing a great burden on existing programs in vocational and technical education. The severe shortage of curriculum experts and teaching personnel has been a traditional problem throughout the national scene.

A research and development project now under way at Pennsylvania State University is attempting to solve these and other problems in vocational-technical education. The purpose of the project (supported in part by the Bureau of Research, USOE) is to prepare course material in the three core areas—technical mathematics, communications skills, and engineering science—suitable for youth and adults in the first two years of post-high-school technical education. These materials are presented to students at a typewriter terminal with an audiovisual display unit controlled by a computer.

What is Computer-Assisted Instruction?

Computer-assisted instruction (CAI) is, in reality, instruction prepared by a human teacher for presentation under computer control. Experienced teachers prepare materials for a teaching program. The student receives instruction by means of slides, tape messages, and typed information. Then, questions and problems are typed and the student responds by typing an individualized answer. The student's responses to questions determine how the instruction will progress. Students who do not fully understand the material are branched to remedial instruction, and thus avoid repetition of old material.

Computer-assisted instruction enables each student to have a device which provides private specialized tutoring. CAI has the potential to accelerate the learning process by avoiding needless repetition of drill after the student has mastered it. It can also be

This diagram shows schematically the computer center and its service areas. The instructor goes to the computation center, types up a new program, or revises an old one, and it is ready to be used by students in the several schools which are hooked up to the center. The computer described in this article can accommodate eight remote teaching terminals, any five of which may operate at same time.

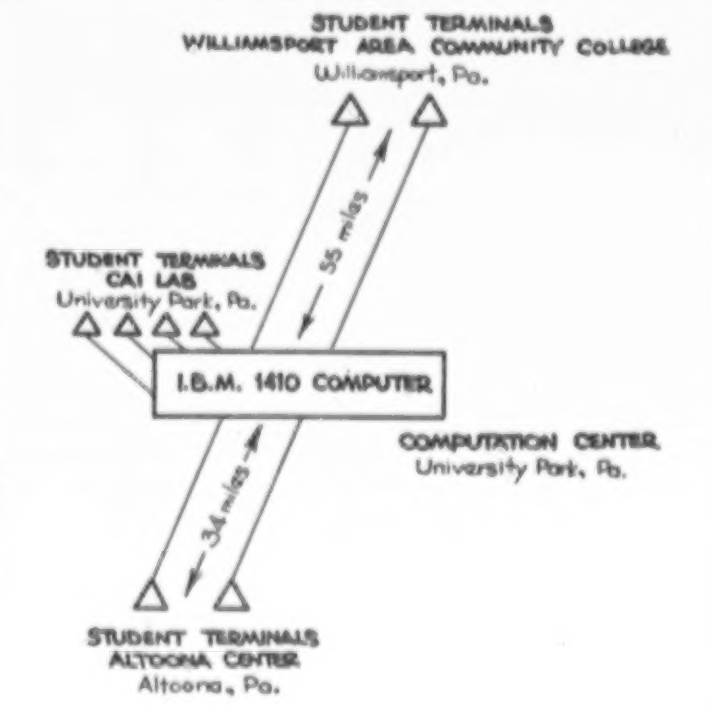

FIGURE 2
Schematic Drawing of Equipment Configuration

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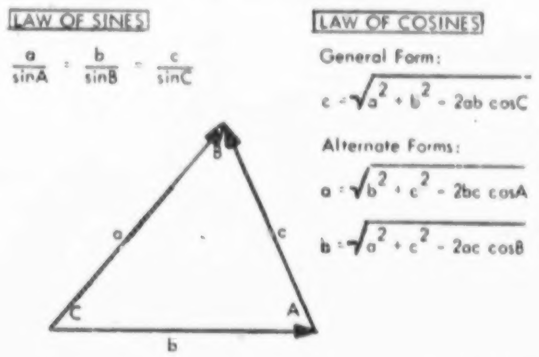
Sample Program

Location	Operation Code	Text
jb-600	rd	
	ty	**The Law of Sines and The Law of Cosines**
	ty	The trigonometric functions are used to solve right triangles. However, many triangles have no right angles. If a triangle has no right angle, special rules are needed to find its sides and angles.
	fn	slide//20
		Slide 20

The Law of Sines and the Law of Cosines



$$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$$

$$c = \sqrt{a^2 + b^2 - 2ab\cos C}$$

$$a = \sqrt{b^2 + c^2 - 2bc\cos A}$$

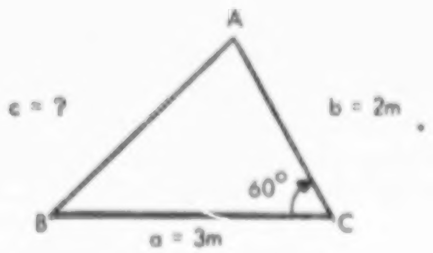
$$b = \sqrt{a^2 + c^2 - 2ac\cos B}$$

Location	Operation Code	Text
jb-630	qu	You could find any angle by using the law of cosines if you knew .... sides.
	nx	

This branch gives the student a similar problem make sure that the concept is clear. After working several problems with 3 sides given, the student is given other unknowns.

Location	Operation Code	Text
jb-640	rd	
	fn	slide//23
		Slide 23

PROBLEM



Location	Operation Code	Text
jb-642	qu	a = 3m b = 2m C = 60 degrees Find side c.
	nx	
	fn	lim
	co	2.5//2.7

The limit function will accept all numbers greater than or equal to 2.5 less than 2.7.

Location	Operation Code	Text
	ty	Correct. The exact answer is **2.6 meters.**
	un	Wrong. Are you using the law of Cosines this way? $c^2 = a^2 + b^2 - 2ab \operatorname{Cos} C$ Type another answer.

Using hints, the author can guide the student who is having difficulty.

Location	Operation Code	Text
	un	$c^2 = (3m)^2 + (2m)^2 - (2 \times 3m \times 2m \times .500)$ $c^2 = 6.8m^2$ c = ...
	un	The correct answer is 2.6m. Type **2.6m.**

The last "un" tells the student the correct answer. In this way, the student who may not be able to find the square root of 6.8 will still be able to proceed.

PROGRAMING COURSES

The segment of the program on the left was taken from a program in trigonometry. The segment deals with the law of sines and the law of cosines. Knowledge of these laws is necessary for the analysis of force vectors, for the determination of velocity components, for finding the components of an alternating current, and for other tasks required in technical occupations.

used to diagnose a student's problems and to provide appropriate remedial measures.

CAI differs from programed texts in that the student's responses are evaluated against anticipated answers stored in the memory of the computer. Since the correct answers are stored in the computer, the student cannot look up the answer and he cannot proceed in the program until he demonstrates that he understands the material.

Some programed texts contain branching programs. These include multiple-choice questions and instructions to turn to a certain page. CAI, as presently developed at Penn State, does not present alternatives to the student, but rather requires that the student construct his own response to each question. The computer compares the student's response with a number of stored possible answers. Correct answers are accepted, the student is provided with encouragement, and is presented with new instruction. When the student gives an incorrect answer, the computer presents a diagnostic comment and branches the student to remedial instruction.

The computer can be programed to present material on the basis of the student's response history or on the basis of other relevant information, such as response time, scores on achievement tests, error rate, or amount of time spent on instruction. Combinations of these criterions may also be used.

CAI offers several potential improvements over the so-called teaching machines. Most teaching machines are merely mechanisms for the presentation of programed texts. In most cases, these devices are used to eliminate page turning or to eliminate the possibility that the student might omit some of the instruction. The instruction which these machines presents is little different from that presented in a programed text. CAI, however, provides greater flexibility in the presentation of material, utilizes audiovisual techniques, evaluates student responses, keeps detailed records of the student's progress, and in a sense, tailors the instructional sequence to each student.

Advantages for Vocational Students

There are a number of reasons why CAI may be advantageous for vocational students. Potentially, it permits an efficient use of expensively and highly trained teachers. An instructor may prepare a program which is then stored in the computer. Many students at several locations may receive instruction through a program prepared by an experienced teacher. A substantial increase in the student-to-teacher ratio is achieved, without providing additional work for the teacher.

Computer-assisted instruction makes possible an acceleration and individualization of instruction which has often been desired in educational theory, but rarely achieved in practice. The computer reacts to features of the student's performance, presents appropriate remedial instruction when a student is not succeeding, and presents accelerated material when a student is insufficiently challenged.

Another factor which assists the student is the gaming interaction between the student and the machine. Here, the role of the machine is that of an opponent with which the student interacts, just as he interacts with problems in laboratories and real situations.

An instructor may update a curriculum which has been programed for the computer by merely typing the program revisions at the typewriter terminal.

Students at the various teaching terminals progress at their own speeds, receiving special, remedial aid when necessary, or acceleration and enrichment if the situation calls for it. This student is receiving what Penn State researchers consider "tailored" instruction.

Often, a complete revision process may be accomplished in one day.

It is not necessary that the instructor be skilled in computer programing. A simple programing language is used which most persons can learn after a few hours of instruction. The most important factor in preparing the course material is that the student must be able to comprehend it. The effectiveness of the program depends on the effectiveness of the teacher who prepares it. It is imperative that the instructor use a carefully planned teaching strategy.

In fact, analysis of the data obtained from students who have received instruction may be used to show the instructor ways to improve his program. The teacher has an opportunity to observe the strengths and weaknesses of his presentation.

The computer we are using is an IBM 1410. It can accommodate eight remote teaching terminals, any five of which may operate simultaneously. Costs for operating the system include computer rental, terminal rental, and telephone transmission charges. Present costs are high. However, larger systems accommodating upwards of 40 remote terminals are possible if a larger computer is used. It has been estimated that the cost of operating such a system could be less than one dollar per hour per student.

Pictured is a typical computer-controlled typewriter terminal and audiovisual unit to which the student goes for instruction. Costs for operating the system include computer rental, terminal rental, and telephone transmission charges.

How CAI Will Serve Education

Since the terminals and audiovisual units are available commercially, it is possible for any institution to use courses programed for computer-assisted instruction. The courses may be used for supplemental on-the-job training, adult retraining programs, and for presenting current techniques and information to employes, as well as for instruction of students in technical institutes.

It is not anticipated that all courses, or that any particular course, would be taught better at a computer terminal than by conventional instruction. However, much of the content of technical and related education can be presented efficiently through CAI. The explorations at Penn State are helping to clarify how the computer will be effective in occupational education.

APPENDIX C

C.1 Student Attitude toward Computer-Assisted Instruction

C.2 Spelling Achievement Test

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APPENDIX C

STUDENT ATTITUDE TOWARD COMPUTER ASSISTED INSTRUCTION

COMMUNICATION SKILLS

This is not a test of information; therefore, there is no one "right" answer to a question. We are interested in your opinion on each of the statements below. Your opinions will be strictly confidential. Do not hesitate to put down exactly how you feel about each item. We are seeking information, not compliments; please be frank.

NAME: ______________________________ DATE ____________________

NAME OF COURSE ____

CIRCLE THE RESPONSE THAT MOST NEARLY REPRESENTS YOUR REACTION TO EACH OF THE STATEMENTS BELOW:

1. While taking Computer Assisted Instruction I felt challenged to do my best work.

:	:	:	:	:
Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

2. The material presented to me by Computer Assisted Instruction caused me to feel that no one really cared whether I learned or not.

:	:	:	:	:
Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

3. The method by which I was told whether I had given a right or wrong answer became monotonous.

:	:	:	:	:
Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

4. I was concerned that I might not be understanding the material.

:	:	:	:	:
Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

5. I was not concerned when I missed a question because no one was watching me anyway.

:	:	:	:	:
Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

6. While taking Computer Assisted Instruction I felt isolated and alone.

:	:	:	:	:
All the time	Most of the time	Some of the time	Only occasionally	Never

7. While taking Computer Assisted Instruction I felt as if someone were engaged in conversation with me.

:	:	:	:	:
All the time	Most of the time	Some of the time	Only occasionally	Never

8. The responses to my answers seemed appropriate.

:	:	:	:	:
All the time	Most of the time	Some of the time	Only occasionally	Never

9. I felt uncertain as to my performance in the programmed course relative to the performance of other.

:	:	:	:	:
All the time	Most of the time	Some of the time	Only occasionally	Never

10. I found myself just trying to get through the material rather than trying to learn.

:	:	:	:	:
All the time	Most of the time	Some of the time	Only occasionally	Never

11. I knew whether my answer was correct or not before I was told.

:	:	:	:	:
Quite often	Often	Occasionally	Seldom	Very seldom

12. I guessed at the answers to questions.

:	:	:	:	:
Quite often	Often	Occasionally	Seldom	Very seldom

13. In a situation where I am trying to learn something, it is important to me to know where I stand relative to others.

:	:	:	:	:
Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

14. I was encouraged by the responses given to my answers of questions.

:	:	:	:	:
Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

15. As a result of having studied some material by Computer Assisted Instruction, I am interested in trying to find out more about the subject matter.

:	:	:	:	:
Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

16. In view of the time allowed for learning, I felt too much material was presented.

:	:	:	:	:
All the time	Most of the time	Some of the time	Only occasionally	Never

17. I was more involved in running the machine than in understanding the material.

:	:	:	:	:
All the time	Most of the time	Some of the time	Only occasionally	Never

18. I felt I could work at my own pace with Computer Assisted Instruction.

:	:	:	:	:
Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

19. Computer Assisted Instruction makes the learning too mechanical.

:	:	:	:	:
Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

20. I felt as if I had a private tutor while on Computer Assisted Instruction.

:	:	:	:	:
Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

21. I was aware of efforts to suit the material specifically to me.

:	:	:	:	:
Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

22. I found it difficult to concentrate on the course material because of the hardware.

:	:	:	:	:
All the time	Most of the time	Some of the time	Only occasionally	Never

23. The Computer Assisted Instruction situation made me feel quite tense.

:	:	:	:	:
Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

24. Questions were asked which I felt were not relevant to the material presented.

:	:	:	:	:
All the time	Most of the time	Some of the time	Only occasionally	Never

25. Computer Assisted Instruction is an inefficient use of the student's time.

:	:	:	:	:
Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

26. I put in answers knowing they were wrong in order to get information from the machine.

:	:	:	:	:
Quite often	Often	Occasionally	Seldom	Very Seldom

27. Concerning the course material I took by Computer Assisted Instruction, my feeling toward the material before I came to Computer Assisted Instruction was:

:	:	:	:	:
Very favorable	Favorable	Indifferent	Unfavorable	Very unfavorable

28. Concerning the course material I took by Computer Assisted Instruction, my feeling toward the material after I have been on Computer Assisted Instruction is:

:	:	:	:	:
Very favorable	Favorable	Indifferent	Unfavorable	Very unfavorable

29. I was given answers but still did not understand the questions.

:	:	:	:	:
Very often	often	Occasionally	Seldom	Very Seldom

30. While on Computer Assisted Instruction I encountered mechanical malfunctions.

:	:	:	:	:
Very often	Often	Occasionally	Seldom	Very Seldom

31. Computer Assisted Instruction made it possible for me to learn quickly.

:	:	:	:	:
Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

32. I felt frustrated by the Computer Assisted Instruction situation.

:	:	:	:	:
Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

33. The responses to my answers seemed to take into account the difficulty of the question.

:	:	:	:	:
Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

34. I could have learned more if I hadn't felt pushed.

:	:	:	:	:
Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

35. The Computer Assisted Instruction approach is inflexible.

:	:	:	:	:
Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

36. Even otherwise interesting material would be boring when presented by Compter Assisted Instruction.

:	:	:	:	:
Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

37. In view of the effort I put into it, I was satisfied with what I learned while taking Computer Assisted Instruction.

:	:	:	:	:
Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

38. In view of the amount I learned, I would say Computer Assisted Instruction is superior to traditional instruction.

:	:	:	:	:
Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

39. With a course such as I took by Computer Assisted Instruction, I would prefer Computer Assisted Instruction to traditional instruction.

:	:	:	:	:
Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

40. I am not in favor of Computer Assisted Instruction because it is just another step toward de-personalized instruction.

:	:	:	:	:
Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

41. My typing training and experience has been:

:	:	:	:	:
Very Extensive	Extensive	Some	Little	Very Little

42. Typing experience is necessary in order to perform easily on the machine.

:	:	:	:	:
Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

43. I think Computer Assisted Instruction would be best for learning:

:	:	:	:	:
Spelling	Punctuation	Grammar	Report Writing	Vocabulary

44. How long do you feel you could work efficiently in computer guided instruction at one sitting? (circle one)

Half hour   1 hour   1-1/2 hours   2 hours   More than 2 hours

(Approx. how many hours ________)

THIS SPACE IS PROVIDED FOR ANY COMMENTS YOU CARE TO MAKE ABOUT COMPUTER ASSISTED INSTRUCTION.

Appendix C.2

Achievement Test

Thirty-seven words are pronounced by tape, used in sentences, and pronounced again. The student then types the word. At the conclusion of the test, the score is typed out with an indication of the kinds of errors made. There is a possibility of fifty errors in the following 37 words:

1. deceitful
2. echoes
3. dyeing
4. laboratory
5. two-thirds
6. quiet
7. principle
8. calendar
9. armies
10. prescribe
11. achieving
12. derivative
13. self-improvement
14. formerly
15. capital
16. privilege
17. knives
18. circumference
19. bountiful
20. piece
21. can't
22. access
23. complement
24. mathematics
25. theses
26. intercede
27. angrily
28. vein
29. they'll
30. personal
31. invisible
32. thieves
33. relies
34. temperature
35. thirty-one
36. instance
37. grammar